DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 273

# QUALITY OF THE WATER SUPPLIES OF KANSAS

BY

HORATIO NEWTON PARKER

WITH A

## PRELIMINARY REPORT ON STREAM POLLUTION BY MINE WATERS IN SOUTHEASTERN KANSAS

BY

E. H. S. BAILEY

PREPARED IN COOPERATION WITH THE
KANSAS STATE BOARD OF HEALTH

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# QUALITY OF THE WATER SUPPLIES OF KANSAS.

By Horatio Newton Parker.

## INTRODUCTION.

The variety of uses to which water is put by man has increased with the evolution of the race. Uncivilized people used water chiefly for drinking, cooking, and cleansing, and the very little necessary to suffice them could be found in all except the arid regions. When men became herdsmen, roving from place to place with their animals in search of good grazing, more water was needed; wherever the water supply was short various devices were adopted to conceal wells, and many bitter feuds rose out of disputes over water supplies. Later, when men adopted permanent abodes and became farmers, came the additional need of water for irrigating crops; the development of mining created another use for water; and finally came the complex life of the modern city, which demands water for a multitude of uses besides slaking thirst, washing, and cooking. To supply the necessities of a twentieth century city a public water supply must be both sufficient in quantity and of satisfactory quality. An inadequate supply tends to foster habits of uncleanliness, hampers industrial development, and exposes a city to the danger of destruction by fire. The quality of the water of a public supply may be as important as its abundance, though for some uses quality is unimportant. For fire protection salt water does as well as fresh, but for many other uses to which water is put its character is of prime importance. For example, so many ravaging epidemics of Asiatic cholera and typhoid fever have been traced to polluted water that it is now recognized that water defiled by human excrement is unsafe to drink because at all times it is likely to contain the germs of disease. Water used in washing wool must be soft in order that the wool may not feel harsh. Soft water, also, must be used to wash goods that are to be dyed in order that they may take the dyes evenly. In laundering, hard waters are most undesirable because they consume a great deal of soap and because clothes washed in them are not bright and white. In locomotive and stationary boilers the quality of water used is of the utmost importance, for some waters corrode them and others deposit in them a scale which by reason of its nonconductivity increases the coal consumption and also renders the boiler liable to explosion. These are but a few examples of the industries which might be mentioned in which the quality of water used is a factor in determining the grade of goods and the cost of their production.

A public water supply may be developed from either surface or underground sources. In the United States more public water supplies are derived from ground water than from impounded surface waters or from flowing streams; but the total consumption of water in cities using ground water is far less than in those using surface waters. This is because ground-water supplies sufficient for a large city are available only in exceptional localities, and growing cities must therefore in time seek supplies from surface waters.

The best surface-water supplies are those that are collected in large reservoirs on catchment areas that are sparsely populated and that are guarded by sanitary police. Under such conditions pollution is reduced to a minimum, and while the water is held in the big storage reservoirs its suspended matter settles out, it is bleached by the sunlight, and the pathogenic bacteria that it may carry are reduced in numbers by sedimentation, insolation, and other factors. Water supplies of this kind rank amongst the safest, yet it seems impossible to protect them against chance pollution, and some of the most disastrous epidemics of typhoid fever that have occurred in this country originated on drainage areas that were believed to be perfectly guarded from contamination.

The worst surface supplies are those that take the unpurified water of rapidly running streams whose drainage areas above the intake of the waterworks are thickly populated. Such water is too polluted to be safely potable, and it is likely to be so impaired by trade wastes as to be inferior for use in the arts and industries.

It is evident, therefore, that an ample supply of good water is not easy to obtain. Consequently water has a money value which is small in some regions but is greatly enhanced wherever scarcity of rainfall, unfavorable geological conditions, a dense population, or unrestrained pollution makes the competition for water keen. So great is the value of water in some sections of the country that corporations have secured control of the best sources of supply, and municipalities have spent immense sums of money in procuring waters. In one State, at least, the burden of procuring water supplies in its most densely populated section has been deemed too great for the cities to shoulder, and the State itself has developed a comprehensive plan for providing water for the cities and a part of the works are already in operation. Another State, recognizing that its plenteous water supply might be made a factor in attracting capital and in other ways making its cities prosperous, has passed a law prohibiting the piping of its natural waters outside of the State boundaries. In fine, water is a great natural resource with a constantly increasing value.

To take account of this asset of the State of Kansas has been the object of this investigation. Measurements of the quantity of water flowing in the larger rivers of Kansas were carried on by the United States Geological Survey through a period of years and a summary of the records at each river station is published in the appropriate place in this paper. To determine the quality of surface waters, sampling stations were established as follows:

*Sampling stations on Kansas rivers.*

| River. | Sampling station. | Collector. | Period. |
|---|---|---|---|
| Arkansas | Deerfield | Chas. E. Gordon; C. E. Hogle | Dec. 11, 1906, to Dec. 2, 1907. |
| Do | Great Bend | M. L. Roseborough; S. M. Smith | Nov. 26, 1906, to Dec. 7, 1907. |
| Do | Arkansas City | A. L. Newman | Dec. 7, 1906, to Dec. 10, 1907. |
| Big Blue | Manhattan | Ed. Marksheffel | Dec. 19, 1906, to Dec. 20, 1907. |
| Chikaskia | Argonia | E. McCann | Nov. 30, 1906, to July 5, 1907. |
| Cimarron | Englewood | Geo. Berends | Nov. 30, 1906, to Nov. 30, 1907. |
| Cottonwood | Emporia | John M. Hilton | Dec. 4, 1906, to Dec. 3, 1907. |
| Delaware | Perry | C. G. Hart | Jan. 4 to June 28, 1907. |
| Do | Valley Falls | Geo. Harmon | June 12 to Nov. 29, 1907. |
| Fall | Neodesha | J. J. Carroll | July 1, 1907, to June 10, 1908. |
| Kansas | Holliday | E. W. Johnson | Dec. 29, 1906, to Dec. 31, 1908. |
| Marmaton | Fort Scott | Jas. Burton | Feb. 1, 1907, to Feb. 1, 1908. |
| Medicine Lodge | Kiowa | Lou Bedwell; R. L. Vandusen | Jan. 22, 1907, to Sept. 11, 1907. |
| Missouri | Kansas City, Mo | E. M. Purdue | Oct. 4, 1906, to Oct. 21, 1907. |
| Neosho | Emporia | Frank A. Bacon | Dec. 5, 1906, to Dec. 5, 1907. |
| Do | Oswego | Nelie Nafus | Dec. 11, 1906, to Dec. 9, 1907. |
| Osage | Boicourt | J. W. L. Gray | Nov. 29, 1906, to Nov. 30, 1907. |
| Prairie Dog Creek | Long Island | Frank Swart; A. H. Mischke | Dec. 6, 1906, to Dec. 4, 1907. |
| Republican | Junction | J. H. Rathert | Nov. 26, 1906, to Sept. 10, 1907. |
| Saline | Sylvan Grove | Edw. Buehring | Nov. 27, 1906, to Nov. 29, 1907. |
| Sappa Creek | Oberlin | C. S. Maddox | Nov. 28, 1906, to Jan. 9, 1907. |
| Smoky Hill | Lindsborg | P. E. Gibson | Nov. 27, 1906, to Nov. 29, 1907. |
| Solomon | Beloit | A. T. Rodgers | Dec. 1, 1906, to Dec. 5, 1907. |
| Spring | Baxter Springs | Paul E. Mason | Dec. 1, 1906, to Nov. 30, 1907. |
| Verdigris | Coffeyville | D. M. Blair | Dec. 11, 1906, to Dec. 10, 1907. |
| Walnut | Winfield | Winfield Roller Mill & Elevator Co. | Dec. 1, 1906, to Nov. 26, 1907. |

At each of these stations there was collected each day a 111 cubic centimeter sample of water, which was sent to the University of Kansas at Lawrence. There the samples for each 10 successive days were combined into a single composite sample, which was analyzed. The quality of the minor affluents was approximated by water assays that were made in the field by representatives of the United States Geological Survey, and the quality of the ground waters of the State was determined by analyses and assays. To find out how fully and how wisely the waters of the State had been utilized, the public water supplies were investigated, and the sewerage and methods of disposing of offal in the cities were looked into in order that the injury done to surface and underground water by sewage and other wastes might be known. In connection with these studies samples of water were tested at the University of Kansas for the presence of *Bacillus coli.*

This report, which presents the results of the investigation, also describes briefly the salient features of the geology of the State in order that its relation to the water supply may be understood.

The field work covered the period from October 5, 1906, to February 9, 1908.

It is believed that although the details of certain areas yet remain to be worked out, the fundamental facts concerning water supplies in Kansas are fully set forth.

## ACKNOWLEDGMENTS.

The investigation of the quality of Kansas waters was prosecuted under a joint agreement between the Kansas State Board of Health and the United States Geological Survey. As originally planned, the work was of broader scope than the results in this report indicate, but defects in the law passed by the Kansas Legislature providing for the investigation made certain funds that it was intended to appropriate unavailable, and the work had to be curtailed.

The United States Geological Survey paid the salary of an engineer in the field for 16 months, the expenses of operating 23 sampling stations for 11 months, and those of writing and publishing this report. The State Board of Health of Kansas paid for the maintenance of 23 sampling stations for one month and of 1 station for a year. The board also paid the traveling expenses of an engineer in the field. Dr. S. J. Crumbine, secretary of the board, made many useful suggestions pertaining to the work and furthered it in every possible way.

As the law of Kansas provides that the scientific work of the State board of health shall be done at the University of Kansas, the university became an active participant in the study. Through Chancellor Frank Strong, to whom hearty thanks are due for his sincere efforts to carry the work to a successful conclusion, the facilities of the chemical, bacteriological, engineering, and geological departments of the university were made available. In the chemical laboratories, under the direction of E. H. S. Bailey, F. W. Bushong, Archie J. Weith, and others analyzed the composite samples from the 23 sampling stations on the principal streams of the State. In the bacteriological laboratories, under the direction of M. A. Barber, W. A. Stearin tested for the presence of *Bacillus coli* samples of water which were forwarded for examination from the many public water supplies of the State by an engineer of the United States Geological Survey. In the department of civil engineering F. O. Marvin was often consulted, and W. C. Hoad, in his capacity as sanitary engineer of the State board of health, supplied descriptions of waterworks and sewerage systems that were built after field work by the United States

Geological Survey was closed. In the department of geology Erasmus Haworth, State geologist, gave valuable assistance. As State geologist he granted permission to have copies of the geologic map of the State that was prepared under his direction, and that appears in this report, struck from the stone owned by the Kansas University Geological Survey. Attention should be called to the fact that although the State geologist has permitted the map to appear with a slightly different legend from that prepared by him, his approval of the changes is not necessarily implied.

The chemical analyses in the section of this report that treats of the quality of ground waters are almost wholly the work of industrial chemists who have generously given their work for publication. For this liberality particular thanks are offered W. A. Powers, chief chemist of the Atchison, Topeka & Santa Fe Railway; M. Miller, superintendent of water service, Missouri Pacific Railway; N. F. Harriman, chemist and engineer of tests, Union Pacific Railroad; J. B. Berry, chief engineer of the Chicago, Rock Island & Pacific Railway; T. E. Calvert, chief engineer, and M. H. Wickhorst, engineer of tests, of the Chicago, Burlington & Quincy Railroad; C. R. Gray, second vice president of the St. Louis and San Francisco Railroad, and the Kennicott Water Softener Co. The analyses by these chemists and by others were stated in hypothetical combinations and have been recalculated to the ionic form in the offices of the United States Geological Survey.

In the summer of 1905 Edward Bartow and a representative of the United States Geological Survey made many water assays in the valleys of Verdigris, Spring, and Neosho Rivers, and these assays appear in this report. All the water assays that are published in this volume were made by H. N. Parker, of the United States Geological Survey, unless it is specifically stated that they were made by some one else.

The stream flow data that appears in this report was compiled from the records of the United States Geological Survey by R. H. Bolster.

Many citizens of Kansas helped on the work. The Kansas Sanitary League and the Kansas Water, Gas and Electric Association indorsed the investigation and helped through their secretaries, W. A. S. Bird and James D. Nicholson. J. W. Berryman, of Ashland; C. L. Becker, of Ottawa; W. E. Hutchinson and O. L. Helwig, of Garden; W. W. Cockins, jr., of Crooked L ranch, Meade; C. D. Perry, of Claremont ranch, Englewood; W. E. Sweezy, of Junction; and B. F. Eyer, of Manhattan, have all assisted in different ways. A. T. Rodgers, of Beloit; C. S. Maddox, of Oberlin; A. L. Newman, of Arkansas City; the Winfield Roller Mills & Elevator Co., the St. Louis & San Francisco Railroad, and the cities of Coffeyville, Fort Scott, Junction,

Manhattan, Oswego, and Valley Falls maintained daily sampling stations for the United States Geological Survey at their own expense. It is impossible to give credit to all who have supported the investigation of the quality of Kansas waters, but the spirit in which the study was welcomed contributed to whatever degree of success has been attained.

## REMARKS ON CHEMICAL ANALYSES OF WATER.

Water has been called the universal solvent, and though the statement is somewhat exaggerated, most substances of common occurrence yield to its solvent action. Some things water dissolves very quickly, but others succumb to its attacks so very slowly that it is not apparent that solution is being effected.

Rain and snow in the act of falling, before they have come in contact with the earth, are water in the purest state known in nature; but even such water is not absolutely pure, for in falling from the clouds the water dissolves from the atmosphere certain gases, such as carbon dioxide, and certain mineral substances, such as chlorides, derived from the dust which is wafted high into the air by the wind. Rain water, indeed, exhibits great differences in quality, for that which falls in the clear atmosphere of a high mountain peak is decidedly purer than that which falls through the smoky, dirty air of a manufacturing city. But the amount of inorganic matter dissolved by rain and snow in falling from the clouds to earth is small, and such tests as have been made indicate that the total dissolved solids vary from 2 to 10 parts per million.[1]

As soon as this very slightly mineralized water reaches the ground it begins to attack actively the rocks on which it falls. In humid regions most of the readily soluble salts are washed out of the ground, and as the surface water does not remain long in contact with the soil it does not become highly mineralized. In such regions, therefore, the surface water is as a rule softer than that from wells and springs. In arid regions and in regions where rainfall is markedly deficient the processes of rock weathering keep pace with the leaching of the soil, and the easily soluble salts accumulate as fast as or faster than they are removed by water; hence when rain does fall that which runs off over the surface is very nearly as highly mineralized as the ground water. The water of springs and wells is likely to be hard, as it is derived from that portion of the rainfall which sinks into the ground and circulates so slowly through the rocks that solvent action is exerted for a long time; and unless the region comprises chiefly granitic and other igneous rocks very resistant to solution, the water may pick up considerable mineral matter, for most sedimentary rocks

[1] Richards and Woodman, Air, water, and food, p. 197.

yield readily to solution. Temperature and pressure are also factors that in a measure determine the vigor of the solvent action of water.

The ability of water to dissolve limestones and some other rocks is increased by its absorption of carbonic acid in passing through the upper layers of the soil, where the decomposition of organic matter is in process. Such rocks are very effectively attacked, as is shown by the caves and underground passages found in many limestone regions. Some of the "sink holes" in the Kansas prairies have been caused by the subsurface solution of the limestone beds which allowed the land above the solution cavities to fall in.

The amount of erosion and chemical denudation accomplished by the circulation of water is very great. Some inkling of its importance may be had from studying the tables which show the amount of matter transported by the Kansas and other streams. (See especially tables on pp. 243–247.)

In presenting the results the terms "hard" and "soft" are applied to waters, and the several constituents are said to be low, moderate, high, or great. Such descriptive words are used in a purely relative sense and from the point of view of the Kansan. Most of the waters of the State are excessively mineralized as compared with the soft waters of New England, but this fact is unknown to the average citizen of the State, or at least he does not use the New England waters as a standard in grading the waters of his own State. He rates a water by comparing it with those waters in general use about him and people in other States do the same. Hence, although in Kansas and elsewhere the terms cited have a local and somewhat inexact meaning, they yet convey fairly definite ideas. In Kansas the waters that are generally called hard contain over 300 parts of $HCO_3$, or over 40 parts of $SO_4$, in equilibrium with calcium and magnesium, and in this report this interpretation of the popular term has been followed. In one other matter the public should be cautioned—that is, that the words "fair," "good," and "excellent," as used in this report in discussing mineral analyses of waters, have no reference whatsoever to the potability of the waters.

The methods used in making complete mineral analyses of the samples from the daily sampling stations maintained by the United States Geological Survey in Kansas are those described by Dole.[1]

## SIGNIFICANCE OF MINERAL CONSTITUENTS OF WATER.

Mineral analyses of waters are made to determine the character and amount of mineral matter the waters hold in solution. Ordinarily silica, iron, calcium, magnesium, sodium, potassium, carbonates, bicarbonates, sulphates, nitrates, chlorides, and total dissolved

[1] Dole, R. B., The quality of surface waters in the United States, Part I, Analyses of waters east of the one hundredth meridian: Water-Supply Paper U. S. Geol. Survey No. 236, 1909 pp. 9-26.

solids are determined. In the more refined mineral analyses of waters, such as those of medicinal springs, it is customary to determine other elements, such as aluminum, arsenic, lithium, and manganese. These are usually present in minute amounts and are generally unimportant in municipal and industrial supplies, but sometimes even these rarer metals are significant. There are varieties of *Crenothrix*, for instance, which instead of constructing their sheaths of the iron in the water, as the common variety does, utilize manganese or aluminum for sheath building.[1]

The general import of the common mineral constituents of water are briefly discussed in the following pages, but the reader should remember that the statements are only broadly true, and that a chemist with a knowledge of waters of exceptional character would perhaps modify them.

Silica and carbon dioxide are supposed to be dissolved independently in water, the silica as a colloid and the carbon dioxide as a gas. The other constituents are supposed to be in chemical equilibrium, and the analytical results are expressed in terms of the radicles thus held balanced in solution. The radicles are iron (Fe), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), carbonate ($CO_3$), bicarbonate ($HCO_3$), sulphate ($SO_4$), nitrate ($NO_3$), and chlorine (Cl). The many analyses made by chemists not connected with the United States Geological Survey originally expressed the constituents as being in hypothetical combination; but for the sake of uniformity such analyses have been recomputed in the offices of the Survey to the form of statement here adopted.

*Carbon dioxide* ($CO_2$).—Free carbon dioxide is reported in but few of the analyses that appear in this report for the reason that in the course of the analytical work only a few tests for it were made. The determination of carbon dioxide should always be made in the field, because the amount contained in a sample of water changes almost as soon as the water is collected.

The presence of much carbon dioxide in a water promotes the growth of microscopic organisms [2] and also effects the solution of lead, zinc, and copper from service pipes.[3]

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[1] Jackson, D. D., A new species of *Crenothrix:* Trans. Am. Micr. Soc., vol. 23, 1901, pp. 31–39; The precipitation of iron, manganese, and aluminum by bacterial action: Jour. Soc. Chemical Industry, vol. 21, 1902, pp. 681–684; *Crenothrix* as a source of trouble in public water supplies: Eng. News, vol. 48, 1902, pp. 175–176.

[2] Whipple, G. C., and Parker, H. N., On the amount of oxygen and carbonic acid dissolved in natural waters and the effect of these gases upon the occurrence of microscopic organisms: Trans. Am. Micr. Society, vol. 23, 1901, pp. 103–144.

[3] Clark, H. W., An investigation of the action of water upon lead, tin, and zinc, with especial reference to the use of lead pipes with Massachusetts water supplies: Thirtieth Ann. Rept. Massachusetts State Board of Health, pp. 542–585; Continuation of an investigation of the action of water upon metallic or metal-lined service pipe, and methods for the separation and determination of metals in water: Thirty-second Ann. Rept. Massachusetts State Board of Health, 1900, pp. 487–506.

*Silica* ($SiO_2$).—Silica is present in most waters only in small amounts and it is usually regarded as a constituent of minor importance. In boiler waters it is an incrustant, however, and W. P. Headden [1] has noted that in some slightly mineralized waters which contain much silicic acid the silica forms considerable quantities of scale. In one boiler, which had been in service four years and had been fed with artesian water, the incrustation formed on the tubes was one-fourth of an inch thick and consisted of silicic acid and lime, 76 per cent of the former and 24 per cent of the latter, including a small amount of alkalies. Siliceous deposit has also been observed in steam pipes and vacuum pans in sugar refineries.[2]

*Iron.*—Iron, if found at all, is present in most natural waters only in small amounts, but waters contaminated by certain mine drainage and by certain industrial wastes carry very considerable quantities of iron. In some mineral springs iron is the constituent which imparts a medicinal value to the water, but ordinarily it is undesirable. A half part per million is detectable by taste and more than 4 or 5 parts make a water unpalatable. More than 2.5 parts per million in water used for laundering makes a stain on clothes. Iron must be removed from water from which ice is made or a cloudy discolored product will result. An iron content of over 2 or 3 parts per million in water used in the manufacture of paper will stain the paper. Iron is harmful in water used for steaming, for it is in equilibrium with acids which inside the boiler become dissociated, with the result that the free acids corrode the boiler plates; but the amount of iron carried in solution by most waters is so small that the damage it does to steam boilers generally amounts to little. In Kansas iron is found in some waters from the fluviatile deposits of Kansas River and in waters from coal and zinc mining regions, and it is sometimes present in other waters of the State.

Waters having high iron content have in some places caused an immense amount of trouble and expense when used as city supplies, for they favor the growth of *Crenothrix* to such a degree that the water pipes become clogged with the iron sheaths of the organism. The removal of iron from water is sometimes easy and sometimes very difficult. The processes for effecting the removal of iron have been carefully described by R. S. Weston.[3]

*Aluminum.*—Aluminum is usually present in water in such small amounts that it is unimportant save therapeutically. In steam boilers it forms an insignificant amount of scale.

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[1] Brown artesian waters of Costilla County, Colo.: Am. Jour. Sci., 4th ser., vol. 27, No. 160, p. 310.

[2] Am. Chemist, vol. 4, 1874, p. 245.

[3] The purification of ground waters containing iron and manganese: Proc. Am. Soc. Civil Eng., vol. 34, pp. 1324–1393.

*Calcium.*—Calcium is the principal scale-forming constituent in water. In carbonate waters it forms soft scale in boilers. But it may be partially removed from such waters by the addition of lime. In sulphate and carbonate-sulphate waters calcium forms hard scale. These waters are often treated with soda ash to remove the calcium. Both carbonate and sulphate waters containing calcium are sometimes treated in a preheater to remove the calcium. The heating of carbonate waters containing calcium results in the precipitation of the calcium as calcium carbonate, as the carbonic acid which holds the calcium in solution is driven off. The heating of sulphate waters carrying calcium results in the precipitation of the calcium as calcium sulphate, which is less soluble in hot than in cold water. Waters high in calcium and chlorides are apt to be corrosive to steam boilers. Waters containing calcium, carbonates, sulphates, and also sodium are in a measure self-corrective, the precipitation of calcium sulphate (hard scale) being largely or even wholly prevented. The behavior of such waters in boilers is difficult to predict, for in actual use they may form a sufficient quantity of hard scale to make trouble, or they may cause foaming.

Calcium is one of the soap-consuming elements in water, and therefore waters with high content of calcium are expensive in the household and laundry because they increase the soap bill.

For several other reasons it is important to know the calcium content of waters. In the salt industry, for instance, sulphate waters high in calcium must not be used to extract salt from the ground, for the salt evaporated from such waters will cake so hard that it is an inferior and sometimes an unsalable product.

*Magnesium.*—Magnesium is present in waters that contain calcium but usually in smaller quantities. From carbonate waters in steam boilers magnesium is precipitated as magnesium carbonate or oxide which forms a scale. The other salts of magnesium are soluble and of themselves do not form scale, but in sulphate waters in which calcium is present they do. Sulphate waters containing calcium and magnesium form a very dense, porcelain-like scale, whereas carbonate waters carrying calcium and magnesium form a friable scale that is very easily removed. Waters containing nitrates, chlorides, or sulphates, and considerable quantities of magnesium are likely to corrode boilers.

*Sodium and potassium.*—In most of the analyses in this report sodium and potassium are not reported separately, it being the belief of the chemists that the amount of potassium is generally so small that it is unimportant except possibly therapeutically. As sodium is a constituent of common salt the waters of saline springs and wells are high in this element.

Carbonate and sulphate waters carrying large amounts of sodium and potassium together with considerable calcium and magnesium are likely to cause foaming in boilers, because in such waters precipitates of calcium and magnesium carbonates and of calcium sulphate are likely to form, and the fine particles of these precipitates serve as points from which steam is liberated. Sulphate and chloride waters high in sodium may act corrosively on boilers, but this tendency is not believed to be as great as in those sulphate and chloride waters in which the magnesium content is high or as in those chloride waters having high calcium.

*Bicarbonates.*—Many tests by water assay of the ground and surface waters of Kansas indicate that carbonates occur but seldom and only in small quantities. The analyses of the composite samples of surface waters at the chemical laboratories of the University of Kansas point to the same conclusion, but these analyses and the assays show that bicarbonates are always present and frequently in large amounts.

*Carbonates.*—In recomputing analyses to the form of statement adopted in this report, the calcium, magnesium, sodium, and other carbonates that appear in the results have been converted to the proper metallic radicle and the radicle $CO_3$ because it is impossible to tell whether there were really some normal carbonates in the water or whether, as is most likely, only bicarbonates were present.

*Sulphates.*—In Kansas, sulphates are common in ground waters from the Blue Rapids, Gypsum City, and Medicine Lodge gypsum areas, in the waters of wells and springs that tap the gypsiferous shales of the Dakota, in the water of shallow wells that tap the "underflow" of Arkansas River, in the water of streams that are cutting through the coal-measure shales, in the waters from wells sunk in these shales, and in the waters of streams that are contaminated by acid mine waters from coal and zinc mines. The quality of these sulphate waters varies according to whether calcium, magnesium, or sodium is predominant. Sulphate waters higher in calcium than magnesium and sodium come from the gypsum areas, the coal-measure shales, the gypsiferous shales of the Dakota, and the mining regions. These waters are commonly called "gyp" waters, and are disliked because of their hardness and because they form hard scale in boilers. Those sulphate waters in which sodium is present in greater quantity than the calcium and magnesium are often found in the shallow wells that derive their water from the "underflow" of Arkansas River. These waters locally are called "alkali" waters, and are so laxative as to be most unpleasant to those unaccustomed to their use. Moreover, they are apt to cause foaming in steam boilers.

*Chlorides.*—The chlorides in Kansas waters are mostly derived from the solution of common salt which is widely distributed through the State. (See pp. 45–49.) Most of the chlorides in the streams and wells probably come from the solution of saliferous shales which are of common occurrence. The quantity of chlorides carried by Kansas waters varies from the very small amount in the waters of the artesian wells at Meade, to the very large amounts in the flowing salt well at Larned and in other salt wells. The distribution of salt in Kansas is so irregular that it does not appear possible to construct a normal chlorine map of the State.

*Volatile and organic matter.*—Nearly all waters contain organic and volatile matter. Spring and well waters usually carry only small amounts. Some ground-water analyses by unnamed analysts show such large quantities of this matter as to arouse the suspicion that the heading "volatile and organic matter" conceals losses in the analyses.

*Total dissolved solids.*—Total dissolved solids are determined by evaporating a measured quantity of water to dryness on the water bath.

*Hardness.*—The hardness of water is of two sorts—temporary and permanent. Temporary hardness is due to calcium and magnesium in equilibrium with carbonates and bicarbonates. Most of the temporary hardness, but not all of it, can be removed by boiling. In many Kansas waters the temporary hardness is very great and the waters in which it is not marked are few. Permanent hardness is due to sulphates, chlorides, and nitrates of calcium and magnesium; these compounds are held in solution by the water itself. This sort of hardness may usually be partially removed by adding certain chemicals to the water, and sulphate waters with a high calcium content may be partly softened by heating.

## CLASSIFICATION OF WATERS.

All natural waters are more or less impure; that is, they contain in solution substances of different kinds and in widely varying amounts, and the quality of any water is determined largely by the properties of the materials which it holds in solution.

Carbonates and bicarbonates of the alkalies and alkaline earths are common constituents not only of water which flows over the land, as rills, rivulets, rivers, and fresh-water lakes, but also of nearly all underground waters. Solutions of the carbonates and bicarbonates are hydrolized by the water and the hydrolized products impart to the water an alkaline quality.

Sulphates, chlorides, and nitrates of the alkalies and alkaline earths, also present in natural waters, are not affected in this way, so that they impart a saline quality to the water in which they are dissolved.

A classification of natural waters, based upon these considerations, is simple. A water in which the carbonates and bicarbonates exceed the sum of the sulphates, chlorides, and nitrates may be designated alkaline; a water in which the sum of the sulphates, chlorides, and nitrates exceeds the sum of the carbonates and bicarbonates is essentially a saline water.

Besides alkaline and saline waters, there are acid waters. Most acid waters are abnormal, being produced by man in his practice of certain manufacturing and other industries. Thus from dye works, tin-plate works, and galvanizing works, highly acid effluents escape into the stream and convert waters that are naturally alkaline into waters that contain much free acid. Likewise, the water that is drained or pumped from certain mines, such as coal, zinc, or iron mines, is so acid that it often makes the alkaline water of a stream into which it flows decidedly acid.

In naming waters, the prominence of any basic radicle is indicated by prefixing the name of the base to the regular class name, as calcic, magnesic, alkaline, or, sodic saline, but the nomenclature takes account also of the chemical equivalents of the radicles, the amounts of which are expressed in parts per million of water.

*Chemical equivalents.*
(Oxygen=16.)

| | |
|---|---|
| Ca | 20 |
| Mg | 12 |
| (Na+K) | 23 |
| $CO_3$ | 30 |
| $HCO_3$ | 61 |
| $SO_4$ | 48 |
| $NO_3$ | 62 |
| Cl | 35.5 |

The chemical ratio of any two radicles present is the quotient of their amounts in parts per million divided by their respective chemical equivalents.

## TOPOGRAPHIC FEATURES OF KANSAS.[1]

Kansas is a part of the great plain which extends from Mississippi River to the Rocky Mountains. Its northern and southern boundaries stretch 400 miles east and west; its eastern and western reach 200 miles north and south; and its exact area is 82,158 square miles, or somewhat greater than the combined areas of the six New England States, Delaware, Maryland, and the District of Columbia.

The east end of Kansas has an average altitude of approximately 850 feet. Bonita—about the highest point—being 1,075 feet above sea level. Altitudes along its western boundary rise and fall slightly

[1] Abstracted from Kansas Univ. Geol. Survey, vol. 1, pp. 9-15.

from north to south, but hold close to an average of 4,000 feet above sea level. The north and south boundaries have approximately equal elevations, although the increase in height westward is more rapid along the northern side than along the southern. West of Independence the southern line crosses the Flint Hills, which raise the elevation to 1,700 feet, from which it declines again to 1,066 feet at Arkansas City, whence it rises gradually. The lowest point in the State is at the Missouri Pacific Railway depot in Coffeyville, where the elevation is 734 feet. Thus it appears that the general slope of the State is to the east and, consequently, most of the streams flow eastward, but numerous diversions from this course are caused by local flexures and by the character of the materials in which the stream channels are eroded. Thus the streams in the northwestern and northeastern corners of Kansas flow northeastward, those in the southeastern corner flow southwestward, and still others have southeasterly or southerly course. The great incline of the surface as a whole, which, from west to east, for the whole State averages nearly 8 feet to a mile, gives to many of the streams considerable current. In the western part of the State some of the streams have scarcely reached base level, while in the eastern part they have broad level valleys filled in from 20 to 60 feet with alluvial material.

The Flint Hills,[1] which occupy approximately the southern part of Chase County, the western border of Greenwood, Elk, and Chautauqua counties, and the eastern portion of Butler and Cowley counties, contain the headwaters of a number of streams.

Fall River, Elk River, and Big Caney Creek, tributaries of Verdigris River, have their sources in many small streams on the eastern slope of Flint Hills; Cottonwood River, a tributary of the Neosho, sweeps in a broad curve around the northern end of the hills; the South Fork of the Cottonwood heads in them, and the main Cottonwood receives tributary drainage from them. The streams on the west flank of the hills empty into Walnut River. In their southern portion Grouse Creek, flowing in a general southwesterly direction, divides the hills into two ridges, of which the eastern is known as Big Flint Hills and the western as Little Flint Hills. The hills trend in a general north and south direction, the ridge being indicated on the map by the significant names of the towns of Grand Summit, Beaumont, Summit, and Flint Ridge. In their highest parts they are 1,550 feet above sea level. The Flint Hills owe their contour wholly to erosion, the strata lying in nearly horizontal positions, with a dip to the west of 10 feet to the mile and affording no evidence of disturbance. The hills are characterized by even terraces and small canyons and gulches. Along the top of the terraces the several limestone systems of the region are seen in parallel ridges which are very conspicuous on

[1] Kansas Univ. Geol. Survey, vol. 1, pp. 27-29.

account of the whiteness of the rock. The eastern slope of the hills is more abrupt, partly because of the slight western dip, but chiefly because the great shale and sandstone formation, which makes their eastern base, contains much less lime than the hills themselves, and so was much more easily eroded. Big Caney Creek, which flows nearly parallel to the trend of the hills, has cut off a ridge of this material. The hills get their name from the large amount of flint which is strewn over the surface in such profusion as to impede travel and which has been derived by weathering from the limestones.

The State as a whole is an undulating plain, but within it are to be found valleys 200 feet deep, bluffs and mounds 300 feet high, overhanging rocky ledges, and, in many streams, falls. Altogether, it is a country of great beauty and interest.

## GEOLOGY AND UNDERGROUND WATERS.

### GENERAL FEATURES.

Considered as a whole the geology of Kansas is simple; but its details are intricate and require careful investigation before they can be truthfully interpreted. A brief description of the salient features is given herewith. The principal sources of the information were the volumes of the Kansas University Geological Survey, the report of the Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, Professional Paper 32 of the United States Geological Survey, and occasional papers in the transactions of the Kansas Academy of Science, in the reports of the State Board of Agriculture, and in the Kansas University Quarterly. (See Pl. I.)

### PALEOZOIC ROCKS.

#### CARBONIFEROUS SYSTEM.

##### MISSISSIPPIAN SERIES.

The oldest rocks found at the surface in Kansas belong to the Mississippian series and occur in the extreme southeastern corner of the State in an area not exceeding 30 square miles in extent. The series consists of dense limestones with interbedded chert rocks and of the residual products resulting from their superficial decay, and it forms a floor extending indefinitely westward, on which the younger formations of the State rest. In the eastern part of the State this floor dips westward, southwestward, or northwestward, and the superposed strata follow this inclination. This westward dip of the strata and the eastward slope of the land surface bring one stratum after another to the surface; but the westward dip continues scarcely one-third of the distance across the State before it is reversed to the east. The westward dip is produced by the Ozark Hills; the eastward dip is effected by the mighty Rocky Mountain uplift.

### PENNSYLVANIAN SERIES.

Resting upon the Mississippian series, and exposed over the eastern quarter of Kansas, is the Pennsylvanian series, about 3,000 feet thick and commonly divided into the "Upper Coal Measures" and the "Lower Coal Measures." This series consists of alternating beds of limestones, sandstones, and shales, the shales making about four-fifths of its entire thickness. The limestones usually cover wide areas, extending hundreds of miles laterally, and being only 10 to 100 feet thick, are very thin compared to their lateral extent. The sandstones vary in lateral extent from a few yards to a few miles—rarely over 40—and they vary in thickness from a few inches to 50 feet or more. The shale beds extend north and south across the State and from the east end westward as far as they are known. In some places they attain a thickness of nearly 300 feet.

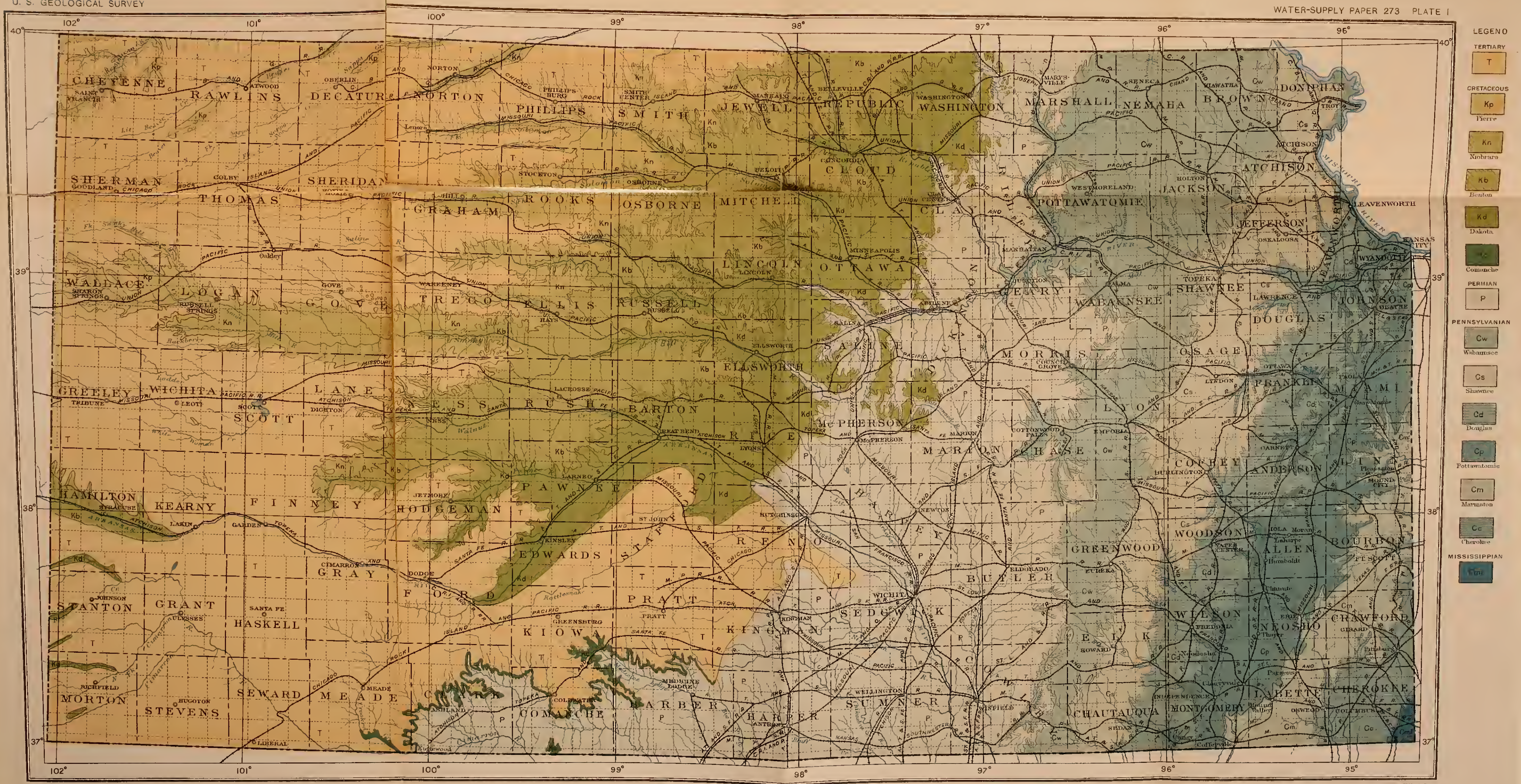
The shales of the Pennsylvanian series are almost impervious to water and rarely yield it in any considerable quantity. Moreover, the water obtained by drilling in the shales and deeply buried sandstones is almost invariably salty. It is useless, therefore, to hope to get a large supply of good water by sinking wells to great depths in the Pennsylvanian rocks. The residual materials—clays, gravels, and sands that overlie this rock series in many places eagerly absorb moisture, and as they are bountifully fed by rain they afford water supplies, sufficient and acceptable for domestic use, everywhere in the eastern part of the State.

### PERMIAN (?) SERIES.

Next above the Pennsylvanian series is a series of rocks which have been called Permian, but which have not been definitely correlated with the true Permian. All that is known is that they are younger than the Pennsylvanian rocks on which they rest and older than the Cretaceous rocks which overlie them. They are exposed in a broad, irregular belt that extends north and south across the State from the northern boundary above Marysville to the southern boundary below Arkansas City. This so-called Permian has been divided by Prosser into the Big Blue "series" and the Cimarron "series."[1]

The Big Blue "series" is made up of shales and limestones. The shales, bluish gray, buff, or varicolored, contain locally beds of gypsum, rock salt, and dolomite; the limestones are cherty. The Cimarron "series" is commonly known as the "Red Beds" and is exposed in Kingman, Harper, Barber, the southern part of Comanche and Clark, and the western part of Sedgwick and Sumner counties. The strong dark-red color of the dominant rocks of this "series" is due to the large amount of red iron oxide that accumulated in the sands and gravels of which they are composed. In places, as for

[1] Jour. Geology, vol. 10, No. 7, p. 702, 1902.




The legend of this map is that used by Erasmus Haworth, of the University Geological Survey of Kansas, with the exception that Pennsylvanian has been substituted for Carboniferous

GEOLOGIC MAP OF KANSAS

Prepared under the direction of Erasmus Haworth, State Geologist

Scale: 1 inch = 24 miles

10 0 10 20 30 40 50 60 Miles

1909

instance at Medicine Lodge, the "Red Beds" contain heavy deposits of gypsum and they are everywhere somewhat heavily mineralized with salt and magnesium sulphate, as well as with other constituents of ocean water. Hence it seems probable that the sediments that form the "Red Beds" were deposited in water which was at one time part of the ocean, but which, by some movement of the earth, was cut off from it and then evaporated till the salts became much concentrated. The absence of fossils from most of the strata of the "Red Beds" implies the same origin, for the water doubtless became too highly mineralized to support life. In their eastern extension the "Red Beds" thin out, but westward they thicken to an unknown extent, probably being over 1,000 feet thick in Meade County. As the "Red Beds" are exceedingly fine-grained and compact, little water percolates through them. Therefore, wells sunk in the "Red Beds" yield only a scanty supply of water that is so highly mineralized by soluble constituents, particularly salt, that it is unfit for domestic use. The surface waters also are highly mineralized with calcium and sulphates in those localities where the gypsum deposits are exposed at or approach the surface.

The Permian (?) shales, below the "Red Beds," are unlikely to afford water except from a sandstone stratum. Water found in either the shale or sandstone, however, would doubtless be unusable because of its high content probably of calcium and sulphates. As neither the "Red Beds" nor the rocks beneath them yield water of good quality, drilling should be stopped as soon as the "Red Beds" are encountered. In places the Permian (?) is mantled by a considerable thickness of unconsolidated material in which many wells are sunk. These yield water of variable character, but most of it is very hard.

## MESOZOIC ROCKS.

### CRETACEOUS SYSTEM.

#### LOWER CRETACEOUS OR COMANCHE SERIES.

In places the "Red Beds" are immediately overlain by the Comanche series, which in this part of the country is about 200 feet thick. It consists of sandstones and shales, and is so limited in extent that it is not a factor affecting the water supply of Kansas.

#### UPPER CRETACEOUS SERIES.

##### DAKOTA SANDSTONE.

*Character and distribution.*—The Dakota sandstone underlies the western half of Kansas, outcropping in a zone 12 to 20 miles wide and extending from Washington County southward and southwestward to Arkansas River. in Rice and Barton counties, and thence up Arkansas Valley to Ford County, where it passes under the Tertiary deposits. It appears again in the valleys of Cimarron River and some of its branches near the Colorado State line. North of Arkansas River, in northwestern Kansas, it passes beneath the Benton, Niobrara, Pierre, and Tertiary formations, probably lying more than 2,000 feet below the surface in the northwest corner of the State. In north-central Kansas it rests on the dark shales and salt beds of the so-called Permian, and to the south and southwest on the "Red Beds" or in places on the Comanche series.

The stratigraphy of the Dakota is so variant that no very distinct subdivisions can be established. At the top of the formation, as defined by the Kansas University Geological Survey, is a thin bed of sandstone, in most places not much more than a foot thick. Next below are shales, varying in thickness from 10 to 20 feet, containing so much gypsum in loose crystals and thin seams that this member has been called the "gypsiferous horizon." Next comes a series of saliferous shales which give rise to many salt marshes and saline springs. The shales range in thickness from 15 to 30 feet and are in many places underlain by a thin bed of lignite, which is locally 2 feet in thickness. The lignite is associated with shale, but commonly lies on or between sandstone. The characteristic member of the Dakota lies next below. It is a thick mass of sandstone with intercalated beds of clays of various kinds. The relations of the shale to the sandstone are exceedingly variable, but in the eastern part of the State well borings show first a series of sandstones, next a mass of shales of considerable thickness, in places amounting to 100 feet, then a second sandstone, 50 or 60 feet in thickness, and then an alternation of sandstones and shales, amounting in all to 300 feet or possibly somewhat more.

The formation is so largely composed of sandstone that it is called Dakota sandstone, though it is probably true that in some localities less than one-half the thickness of the whole Dakota is sandstone. The shales and clays of the Dakota vary much in texture and color. Not uncommonly they are black, but they are generally white, blue, or yellow, with many bands of red or green. The darker shales are, as a rule, argillaceous, while the lighter colors indicate a greater amount of sand. In most places where it is exposed at the surface in Kansas, the sandstone looks rusty, but locally it may be gray, buff, or red, the shade being determined by the amount of brown iron oxide present. In Colorado the color is as a rule very light, even white in places. The quartz grains of which the sandstone is made up vary from one-eighth inch to perhaps one-thousandth inch in diameter, with occasional individuals outside these extremes. In most places the grains are remarkably even in size and the sandstone is of medium texture containing little foreign matter. The cementing material is calcareous and varies considerably in amount, in some places being sufficient to form a hard resistant rock, and in others being so deficient that the sandstone is soft and crumbling. As a rule the calcareous cement is so slight that the rock is porous and capable of holding and transmitting large quantities of water, but where the interstices between the grains are more nearly filled by the cement water conditions are not so favorable.

The Dakota sandstone is distributed over the Great Plains generally and extends westward beyond the eastern range of the western mountains. Originally it must have covered in the United States an area 1,000 miles wide by 2,000 miles long. To-day it outcrops in upturned strata along the western edge of the Great Plains and along their eastern edge. It is not now possible to fix the original eastern limit of the Dakota, for large areas of it were removed by erosion, but remnants are found as far east as eastern Iowa and Minnesota. The Dakota sandstone is one of the most important water-bearing terranes in America. It occurs mostly in arid and semiarid regions and much of it is covered very deeply by younger formations.

The Dakota slopes from the mountains to the eastward, except where local swells interrupt the general inclination of the beds.

*Water supplies.*—The sandstone is almost everywhere water-bearing, though there are places where the grains are too closely cemented, or are too choked with silt and other impurities that were deposited originally with the sand, to admit the passage of water. In portions of the State, particularly the northwest, the Dakota is buried so far beneath the surface that it has not yet been reached by deep borings. The water which the Dakota carries is chiefly derived from rains and snows that fall on its western exposed upturned edges, though large quantities are evidently supplied it by the North Platte, Bighorn, Yellowstone, and other streams that cross the formation. Colonel Nettleton [1] has estimated that at the Great Falls of the Missouri in Cascade County, Mont., as much as 834 cubic feet a second, or about 1,673 acre-feet a day, are lost by the river, and it is believed that nearly all of this vast amount enters the Dakota sandstone. Finally, in areas where the impervious rocks of the Benton group are absent, and the Dakota is immediately overlain by the Tertiary deposits, an opportunity is afforded for an exchange of water between the two formations. How extensive such contacts are is unknown, but it is certain that they exist in two or three places.

As the outcroppings of the Dakota sandstone in Colorado, where it imbibes most of its water, are elevated far above the level of the Dakota in Kansas, the pressure of the wells there that reach it would

[1] S. Doc. No. 41, pt. 2, 1892, pp. 74–78.

be very great were it not relieved in many places where streams have cut deep into the Dakota and also where the rocks outcrop at the eastern margin of the formation. However, the water rises in practically all of the wells that reach the Dakota and many of them are flowing. In the Dakotas and some other places artesian waters from this sandstone have a pressure of 400 pounds to the square inch.

### BENTON GROUP.

The Benton group of rocks extends in a wide belt diagonally across the State, from Republic into Ford and Finney counties, where it passes under the Tertiary deposits, reappearing again along the valley of Arkansas River in Kearny and Hamilton counties. It consists of three formations. The uppermost is a shale known as the Carlile shale. Below this is a formation consisting of thin beds of limestone separated one from another by thin beds of shale, and known as the Greenhorn limestone. These limestone layers are in many places not more than 12 inches thick, yet they have a lateral extent almost as great as the Benton itself, which is believed to be nearly coextensive with the Dakota. One of these limestones is called the "Fencepost" limestone and is of considerable economic importance because it is widely quarried and used for fence posts. The average thickness of the "Fencepost" limestone is 9 inches. A ferruginous seam passes through the center of the layer, and by splitting the limestone along this seam, excellent flagstones are produced. In 1896 it was estimated that at least 50,000 fence posts from this limestone were in use in Mitchell and Lincoln counties alone. Beneath the Greenhorn limestone is a shale known as the Graneros shale. This is the basal formation of the Benton group.

At the summit of the Benton group, embedded in the black shale, occur lens-shaped concretions, varying in size up to 4 or 5 feet in diameter. They are dark colored and are composed largely of carbonate of lime. Some of them are hollow or consist of geodes lined with calcite crystals or traversed by cracks filled with calcite or other minerals. The thickness of the Benton is about 400 feet. The shales of the Benton are nearly impervious to water. This is particularly true of the basal shales of the group (Graneros), which are so bituminous that they emit a strong odor of petroleum. The rocks are known to contain so much salt that any water derived from them would be unfit for domestic use. No considerable amount of usable water can be expected anywhere in this group of rocks.

### NIOBRARA FORMATION.

Above the Benton group are the rocks belonging to the Niobrara formation, which underlie a wide region in Kansas west of the ninety-eighth meridian and north of Arkansas River. The eastern margin of the Niobrara is exposed in a series of slopes rising above the rolling topography of the Benton group and trending southwestward across the State from Jewell County to the northeast corner of Finney County. To the west the Niobrara is thickly overlain by Tertiary deposits, but some of the larger valleys, notably that of Smoky Hill River, are so deeply cut that they afford extensive exposures.

The formation consists of a lower series of limestones, called the Fort Hays limestone, and an upper series of chalks called the *Pteranodon* beds or Smoky Hill chalk. The total thickness of the formation is about 350 to 400 feet, of which the *Pteranodon* beds comprise 300 to 350 feet. These beds immediately underlie the Pierre shale, but the two formations have not been observed in contact in Kansas, owing to the overlap of Tertiary formations.

The *Pteranodon* beds are composed of a massive, light bluish-gray clay, which on weathering becomes yellow or buff, or, in some places, light red, a change due to the oxidation of the iron contained in the deposits. In well borings the material is pale-blue chalky clay, not very sticky when wet. Some rather pure chalk occurs in the formation, notably in the vicinity of Norton in the valley of Smoky Hill River, where it gives rise to many prominent buttes and castellated cliffs. The Fort Hays limestone, by which the *Pteranodon* beds are underlain, is a soft, massive, light-colored rock which weathers out in bluffs of moderate prominence and which is about 50 feet thick. In well boring it is usually distinguished from the *Pteranodon* beds by its increased hardness. Neither member of the Niobrara is water-bearing. Indeed the great chalk beds are as nearly free from water as any formation in the State.

### PIERRE SHALE.

In the northwest corner of Kansas the Niobrara formation is overlain by the Pierre shale, which is exposed at intervals in the valleys of Republican and Arikaree rivers and their branches in Cheyenne County, notably in the banks of Hackberry Creek, 15 miles south of St. Francis; on Beaver Creek, in Rawlins County, and on Prairie Dog Creek, in Norton County. The Pierre consists of heavy, dark grayish-blue shale, that weathers to a rusty yellowish brown and that only here and there contains a small amount of calcareous material. So far as is known, the Pierre has a maximum thickness of 100 feet within the State. The Pierre is entirely devoid of water.

It is evident from the foregoing paragraphs that practically no water is to be obtained throughout the mass of Cretaceous shales and limestones comprised in the Pierre, Niobrara, and Benton formations—aggregating between 800 and 900 feet in thickness. These shales form an impervious floor upon which the water-bearing Tertiary deposits rest, and drilling should cease when the Cretaceous floor is reached, unless it is intended to pass through the barren strata into the Dakota sandstone.

## CENOZOIC ROCKS.

### TERTIARY DEPOSITS.

#### DISTRIBUTION AND CHARACTER.

Overlying a large part of western Kansas, covering, in fact, nearly two-fifths of the entire area of the State, is a mantle of sand, clay, and gravel with a minimum thickness of about 350 feet, which is known to be of Tertiary age. The material is surprisingly regular when considered in a general way, its appearance and composition being so characteristic that it is readily recognized wherever seen. However, it exhibits in detail great differences, varying from exceedingly fine sand to coarse sand or gravel, which in places is made up of pebbles 4 to 5 inches in diameter. The clay is in some places almost pure, but elsewhere it is intimately mixed with fine sand of uniform grains. The arrangement of the material also shows great irregularity, but in general the clay is found on top, immediately at the surface, and has been called the "plains marl." In many localities, however, the surface is of sand 20 to 40 feet deep, with but little clay intermingled, while the clay is liable to be found at any depth below the surface. In places the sand beds are heavy and relatively thick; elsewhere they are thin and interspersed with beds of clay and gravel. The gravel likewise is unevenly distributed. In some places it is found at the base of the Tertiary, but in almost as many it occurs at intermediate levels, and it is not uncommon at the surface. Another very characteristic feature of the Tertiary deposits is the great abundance of calcium carbonate found in them. Samples from many localities showed that at a depth of more than 5 or 6 feet below the surface the deposits contained calcium carbonate enough to effervesce strongly when treated with dilute muriatic acid. In places this calcium carbonate is present in quantities so great that it strongly cements the sand and gravel, forming a firm rock which resists erosion much better than uncemented beds of clays and finer sands. As the result these rocks are generally prominent along the bluffs of various rivers and lesser streams. Such accumulations of sand and gravel of various degrees of coarseness, cemented together as indicated, are called "mortar beds," and almost every stream throughout the whole Tertiary area of the State exposes mortar beds in the upmost part of the material of the bluff. This is notably true along the north bank of Arkansas River from Garden to Dodge along the banks of Sawlog and Buckner creeks to the north of Dodge, along the bluffs of Prairie Dog Creek throughout its course in the Tertiary deposits, along the high uplands on either side of the Saline River, and prominently along Crooked Creek and the Cimarron River in Meade and Seward counties. At Arkalon the mortar beds along the Cimarron are very prominent near the upper level of the bluffs. It was formerly thought that the mortar beds occurred at the base of the Tertiary, but investigation has shown that they occur irregularly, with a tendency to appear near the surface. Nowhere has ground water been found in the mortar beds, and none has been discovered in sand and gravel in which the grains are in any degree cemented by calcium carbonate.

Erasmus Haworth offers the following explanation of the mortar beds: The Tertiary deposits were derived from the disintegration of rocks in the mountainous areas to the west and contain an abundance of finely comminuted calcium carbonate. Rain, in soaking into the ground, picks up from the decaying vegetation carbon dioxide, which reacts on the carbonates in the ground, dissolves them, and carries them into the underground water. In regions of abundant rainfall these carbonates remain in solution; but on the plains, where the rainfall is deficient, the rain carrying the carbonates downward is likely to evaporate or be absorbed by the very dry ground before it reaches the ground water, in either of which cases the carbonates would be precipitated in the ground where they would act as a cement binding together the particles on which they are deposited. Thus the mortar beds might be built up, starting perhaps as small concretions and gradually growing into vast beds.

This explanation of the formation of the mortar beds accounts for their occurrence at different levels in the Tertiary deposits and for their rarity at the base of that system, for the beds would be built up at whatever level the water evaporated, which might be near the surface, somewhat farther down, or even near the bottom; but they would never be formed where there is water containing enough carbon dioxide to hold the carbonates in solution.

## WATER SUPPLIES.[1]

Rainfall over most of the Tertiary area is rather small, but nearly all of it is absorbed, as the ground is very porous. The rain water has very little tendency to flow away over the surface, and such as exists is checked by the sod of buffalo grass, which holds the soil in place and prevents washing. The rain that is absorbed by the Tertiary deposits sinks into the ground until its downward progress is stopped by the Cretaceous rocks, or the "Red Beds" beneath. These rocks form a floor on which the Tertiary deposits rest and which is everywhere impervious, except in the few places where the Tertiary is in direct contact with the Dakota sandstone. If this floor did not

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[1] Report of the Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, pp. 79-87.

exist, water, instead of being generally available throughout western Kansas, would be scarce, for so much of the light rainfall as might collect in pools and ponds would be rapidly dissipated by the intense evaporation, and the rest would sink to unknown depths did not the floor stop it and serve as a surface for it to accumulate on. Before being covered with Tertiary deposits, this floor was a land surface, exposed to the same agencies of weathering and erosion that are at work on the land surfaces of to-day; and, like them, it was cut into valleys, ridges, and hills. Moreover, in the elevation and subsidence to which this floor has been subjected, it has been somewhat warped and bent, so that instead of being perfectly even it is rough. Its inequalities are covered by the Tertiary deposits which lie over them in smooth, level prairies. If the topography of this buried land were known, it would be possible to accurately foretell the depth necessary to drill any particular place to reach the ground water below. But lacking such information, predictions of the depth at which water is to be found must be based on deductions as to the ancient topography, deductions that may be legitimately made from the records of the nearest wells. Such prophecies are, as a rule, fairly dependable, but not invariably so. For instance, the site of a proposed well may be over a valley of the buried land, in which case the depth to water will be unexpectedly great; or the well may be over a hidden ridge and the distance to water be less than anticipated; or the ridge may be so high that it projects above the present underground water level, in which case no water at all can be obtained; and of two wells but a mile or so (or perhaps only a few yards) apart, one may yield no water at all and the other supply it in abundance, because one well is over a ridge and the other is not. Indeed, areas of considerable extent in western Kansas are without ground water because a broad swell in the floor is thus elevated.

The difficulty of predicting the depth at which water will be found is further complicated by the lack of uniformity in the materials which compose the Tertiary and by the irregularity of their arrangement. The sand and gravel deposits ordinarily carry the water, but not where they are at the surface, for there they lie above the underground water level. Only very rarely does the clay contain water, and when a thick bed of it occurs in a spot where a well is to be sunk, the entire clay bed must be pierced before the water-bearing sand below can be tapped. Sometimes such a thick bed is distinctly local and in two neighboring wells the driller must go to a much greater depth for water in one than in the other. Again, the thick bed of clay spreads over a wide area and compels deeper drilling for water than is necessary in a contiguous district.

The water that accumulates above the Cretaceous floor forms what is known as the "underflow," or "sheet water" of the plains. The first, second, and third waters of the plainsmen are found where sheets of clay, occurring one above another, are separated by beds of water-bearing gravel or sand. It is the common impression that these aquifers are in no way related to each other, but as a rule, when all of the clay sheets are penetrated, the lowest water rises to the level of the first, which shows that the different waters are all connected with the great underground supply, which is merely separated into layers by the interposed clay sheets. However, the first water may be more highly mineralized than the others, because the excessive evaporation to which it is exposed concentrates the salts which it carries in solution.

The two popular names, "sheet water" and "underflow," recognize the wide extent and the motion of the ground water of the plains. The motion is imparted by the general tilting of the floor eastward at about the same angle as the inclination of the present land surface. Through the western 100 miles of the State the fall averages 7 to 8 feet to the mile eastward, though local variations occur which turn the flow to the northeast, southeast, or in some other direction at a greatly increased angle. Thus, in the southwestern part of Clark County, the inclination from Minneola to the south line of the State is close to 20 feet to the mile, and in some places, even more than 30 feet to the mile. Likewise, along the south line of the State, in Meade County, the inclination eastward is more than 20 feet to the mile. As the floor is inclined, it is apparent that the sheet water can not everywhere be found at the same depth beneath the surface, although over small areas it appears to be so because the inclination is relatively slight.

This eastward flow of the ground water would completely drain the western county if it were not for the retarding influence of the sand and gravel. In many places the streams have cut through the Tertiary deposits to the Cretaceous floor, and even deep into it. Wherever this has occurred the Tertiary deposits close to the streams are so robbed of their underground water by rapid drainage that good wells are not to be found, but the resistance of the sands to the flow of the water is so great that wells a mile or less away yield abundantly. The size of the particles that compose the sands and gravels is a most important factor in controlling the rate of flow of water, because the water moves much more freely through the coarse material than it does through fine. Hence, a well in a gravel aquifer is likely to be supplied with water so rapidly that vigorous pumping will not lower it very much, whereas a well in an aquifer of compact, fine sand may very probably be fed with water so slowly that it may easily be pumped dry. The flow of the underground water, besides being retarded by the sand, is checked by inequalities of the floor.

Ridges or swells restrain the water just as a dam restrains a flowing stream, and depressions hold it back in the same way that lakes hold back surface waters. Such is the water that is in common use on the plains and has made their development possible. Its presence was unsuspected by the pioneers, many of whom perished for thirst, ignorant of the water beneath their feet.

## QUATERNARY DEPOSITS.

### PLEISTOCENE SYSTEM.

#### EQUUS BEDS.

In McPherson, the western part of Marion, Harvey, and the eastern part of Reno counties is a geologic formation known as the *Equus* beds,[1] which, as shown by well drillings, occupies a channel that was carved out of the Permian (?) shales and Dakota sandstone and that once probably connected Smoky Hill River with Arkansas River. The channel was shallowest at the eastern edge of the area and sloped to the west, where the deepest of the drillings, about 150 feet, have not reached bedrock.

In their broadest part the *Equus* beds are 25 miles across, and they occupy an area about 800 miles in extent north of Little Arkansas River, and, exclusive of the sand hills, 100 square miles south of it. The *Equus* beds are very flat, and offer marked contrast to the rough surfaces presented by the Permian (?) series on the east and the Dakota sandstone on the north.

Little Arkansas River drains the entire area of the *Equus* beds, except a small portion north of the divide, which is drained by Smoky Hill River. As a rule, the area has sufficient slope to drain it, but a chain of lakes and basins extends from McPherson along the western edge of the area over the deepest portion of the buried channel. The largest basin is 2 miles west of McPherson and is nearly 3 miles in diameter, while the largest lake is Lake Inman, 10 miles southwest of McPherson. The divide between Smoky Hill and Arkansas rivers has an average elevation of a little more than 1,500 feet. Arkansas River at the southeastern limit of the area is at 1,290 feet. There is, therefore, a fall of 200 feet in 60 miles. Smoky Hill River at its nearest approach is within 4 miles of the divide, but its bed is nearly 200 feet below it.

The strata that compose the *Equus* beds consist of alternating layers of sand and clay. Near the bottom of the deepest part of the buried channel is a heavy layer of gravel, which everywhere contains an abundance of water. At McPherson it lies at a depth of 140 to 150 feet, or even more. The upper part of this gravel bed grades

[1] The following description of the water from the *Equus* beds has been taken largely from Kansas Univ. Geol. Survey, vol. 2, pp. 288–289, 295–296.

into a stratum, partly argillaceous and partly arenaceous, which is many feet in thickness, and which locally contains isolated sand beds, or at least sand beds of great irregularity, that carry very little water. The upper surface of this stratum is nearly on a level with the rim of the deeper part of the buried channel. On top of this stratum, and extending over a very slightly undulating Permian (?) floor for 15 miles to the east, is a stratum of sand varying in thickness from 30 feet at McPherson (according to S. Z. Sharp) to 3 feet in other places farther east, but averaging 6 to 8 feet in thickness. This stratum also contains a good supply of water and covers nearly the entire area of the *Equus* beds, except a part of the area to the north. The uppermost stratum, which covers the entire area, is 10 to 35 feet thick, and is composed of clay of varying texture and color. In the northern part of McPherson County this clay contains an area of "volcanic ash" 18 to 24 inches thick. The sands of the *Equus* beds have been examined microscopically and appear to be derived from the Dakota sandstone rather than from the rock detritus brought down from the west by rivers.

The *Equus* beds of McPherson County are very fertile, valuable farm land. The region is so flat that almost all of it can be cultivated. Over the eastern part good water is found in abundance at a depth of 18 to 30 feet, being easily reached because the sandy texture of the clay above the water-bearing beds makes digging easy. Over the western part of the area wells 40 to 150 feet in depth furnish an apparently inexhaustible supply of good water. The wonderful amount of water contained in this lower gravel bed of small extent is remarkable. A section through the *Equus* beds from Arkansas River to Smoky Hill River suggests that upon further investigation the water supply may be traced to Smoky Hill and Arkansas rivers. Cottonwood and other trees thrive wherever planted in this area in marked contrast to the area eastward, where the Permian (?) shales form the surface rock and where the cottonwood grows to a fair size and dies.

### DRIFT.[1]

Northeastern Kansas was subject to glacial action. The ice itself crossed the Kaw Valley, not for its whole length but for most of the distance east of Big Blue River. The southwest corner of the ice region is characterized by an immense moraine. East of St. George the tops of the bluffs overlooking Kaw Valley are paved with large bowlders, and on the south side of the valley a little to the east the moraine is simply immense. At the western extremity two hilltops—flat mounds—are paved with bowlders to a depth of 8 or 10 feet, and to the northeast, east, and southeast the moraine extends

[1] Abstracted from report by Robert Hay in Eighth Bien. Rept., Kansas State Board Agr., vol. 13, 1893, pp. 118–120.

for miles. Fully 95 per cent of the bowlders of this moraine are of the red quartzite that comes from South Dakota and Minnesota. The rest are mainly hornblendic greenstone and granite. There are a few fragments of hard limestone that is very common in the drift of North Dakota. A tongue of the glacier was pushed across a low divide here, and continued down to Mill Creek, where the main body of the moraine trends east, still on the south side of the Kaw. At Topeka the river valley was also crossed by a tongue of moraine stretching down to Tevis, 10 miles southeast. At Lawrence, and a few miles south and west, there are again immense morainic deposits. In Missouri they are found farther south than the mouth of the Kaw. Bowlders are found in all counties from the Missouri to the Big Blue. In Washington County they are found west of the Big Blue, and there are also found mounds of gravel and small bowlders, which, if they were not so weathered, would be recognized as osars and kames, which were probably first melted out on the top of the glacier and at last were left in position by the final disappearance of the ice resting on bedrock of the county.

### HARDPAN.

The true hardpan, or till, is a stiff, pasty, dark-brown clay, with pebbles and small bowlders. It seems to have been formed under the ice by the grinding of the material over which the glacier passed—clay, shales, soft limestones, and sand. It is not as extensively found in the glacial area of Kansas as in some other States. It occurs in thin beds in Washington, Pottawatomie, and Nemaha counties and without doubt it exists elsewhere under other deposits. As it forms an intractable soil, it is fortunate that it is not widely found at the surface. Where it exists as a subsoil, drainage is required.

### GUMBO.

A modified hardpan, joint clay, or gumbo of post-glacial origin is found in many places near the surface in the glacial area, and far away from the glaciated region there is a similar deposit. Some of these beds of gumbo are of very recent origin, being the result of floods and weathering by agencies still at work, so that these beds, all strictly local, come down from immediately after the ice to the present day.

### LOESS.

The loess, which is often called bluff, because the bluffs of the Missouri River are formed of it or capped with it from Kansas City to Yankton, is a buff or yellowish marl. Over immense areas it is substantially the same material as that which gives color and muddiness to the water of the present river. In some regions it takes color from local surroundings, contains streaks of coarse sand or gravel, and becomes of orange brightness. It is generally agreed that the loess is the material deposited in the broad lakes and streams that fronted the ice sheet and that followed its retreat to the north. In some regions there is believed to have been an interglacial epoch of milder climate; that is, there was a retreat of the ice sheet for a time and a second advance and repetition of the various phenomena; but in Kansas the whole of the direct glacial phenomena belongs to the oldest ice epoch, and the second ice sheet did not overspread the area. The loess of the second advance, however, overlapped the more ancient loess, although the limits of the overlap have not been worked out. Loess occurs as far west as Dickinson County and Medicine Lodge and down the Arkansas and Neosho valleys into Oklahoma. It is found low down in river valleys and at great elevations in ridges as high as 1,200 feet above sea level in Geary County up to 1,500 in Morris County, and to 1,000 feet in Bourbon County. The so-called "Plains marl" shades into it.

When the Kaw River valley was dammed by ice in Wabaunsee County, the Platte Valley of Nebraska must also have been closed, the Missouri was stopped at Fort Randall, and its waters must have been thrown over Nebraska and northwestern Kansas. The height of the wall of ice must have been sufficient to throw the waters over the high divides to the west and south. Perhaps some Missouri River water, after being spread out into wide lakes, was thrown into the valleys of the Neosho and the Arkansas. Across these waters floated icebergs, large or small, which carried angular bowlders far beyond the ice border, and which are found in the loess that was deposited on the glaciated area during the recession of the ice to the north. Probably at this time the deep trough of Big Blue River was cut by the strong current along the west front of the ice, and the pass cut across Wabaunsee County round the southwest terminal moraine to Mill Creek, whose wide valley below McFarland, filled with deep alluvia, shows that a large stream once worked there. The pass referred to is now used by the Atchison, Topeka & Santa Fe Railway and by the Chicago, Rock Island & Pacific Railway for their tracks from Manhattan to Mill Creek. The tracks at the highest point are little over 100 feet above Manhattan or McFarland, but the neighboring hills are from 200 to 300 feet above the two valleys. The loess has done much to smooth the contour of a region that before this age was very rugged.

### WATERS OF THE PLEISTOCENE ROCKS.[1]

The glacial deposits form a valuable source of water. The meager investigations that have been made on the drift indicate that its

[1] Hay, Robert, Some characteristics of the glaciated area of northeastern Kansas: Kansas Acad. of Sci., Trans., vol. 13, 1891, pp. 104–106.

Swem, E. G., A preliminary report on the glaciated area of Kansas: Kansas Univ. Quart., vol. 4, 1895–96, pp. 153–159.

maximum depth is probably not much more than 175 feet. A well at Holton, 126 feet deep, passes entirely through the drift, and one at White Cloud, 126 feet deep, does not reach rock. Most of the wells that are known to be in glacial deposits range in depth from 40 to 60 feet, though wells of a depth of 70 to 100 feet are not uncommon.

## RECENT DEPOSITS.

### ALLUVIUM.

Many wide valleys in Kansas are covered to a greater or less depth with deposits of alluvial materials brought by the streams at various stages of their development. The process of valley filling following valley erosion is a well recognized phase of river development, resulting from the fact that the transporting power of streams decreases as the channels approach base level. The most extensive of these alluvial deposits is found in the Arkansas River valley, but all the river and creek valleys contain more or less alluvial material of relatively recent origin. The unconsolidated material with which the rivers fill in their valleys is derived from the land along their courses and from mountains near their headwaters, and consists of sand, gravel, clay, and small waterworn rock fragments. This material is admirably adapted for holding water and it yields very valuable water supplies.

The Kansas River valley [1] from Salina to Kansas City is filled in with unconsolidated material derived from the hills along its course, from the mountains to the west, and from glacial material that occurs along its banks. On both sides of the river, but particularly on the north side from the mouth to Topeka, great masses of loess exist along the bluffs. These masses send long streamers down into the valley and so have contributed largely to the fluviatile material. Throughout this part of the valley, which is about 4 miles wide and 150 miles long, and comprises approximately 600 square miles, the alluvial deposits yield an abundant water supply.

Walnut Creek and its tributaries are filled in with alluvial deposits which are water-bearing and which form the principal source of water in the counties drained by this stream.

In the valley of Cimarron River, in Morton, Stevens, and Seward counties, the gravels are near the surface and apparently afford an abundance of water, though their capacity has never been tested. The gravels that have accumulated in the valleys of several of the rivers in the eastern part of Kansas also furnish an abundance of water, but none of them yield so richly as the gravels of the Kansas and Arkansas River valleys.

[1] Kirk, M. Z., The sands of the Kansas River valley: Kansas Univ. Quart., vol. 4, 1895, pp. 125-128.

Not all of the rivers have accumulated gravel in their valleys. Smoky Hill River, for example, is almost entirely devoid of it, although in some places the sand and gravel is 6 feet thick and yields a little water on digging. The water found in these deposits in river valleys is usually derived from the land along the river; that is, it is commonly subsurface drainage of the land that is making its way to the river, but sometimes it is part of the flow of the river. Where water from the fluviatile deposits is to be used for a city supply it is very important to determine its source. If the water is from the river it may be somewhat impure, as the waters of most rivers are polluted; if the water is from the land on its way to the river, it is likely to be pure unless it is nothing more than the underdrainage of a city or town, in which case it should not be developed for a city supply because it is contaminated from such sources as leakage from privies, cesspools, sewers, and the drainage from manure heaps.

### SAND HILLS.

Fine, blown sand, constituting hills and ridges of moderate height with intervening irregular basins and flats, is found in central Kansas, in the Arkansas River valley from Coolidge to Great Bend and on the adjoining slopes to the southeast. This sand has been derived from the alluvial flats along the river and blown out by the prevailing winds, which are strongest from the northwest. Along the river east of Great Bend is an accumulation of sand derived from the Dakota sandstone, and doubtless it yields water to the underflow of the river, though this has not been experimentally demonstrated.

## ARTESIAN WATER.

### CONDITIONS OF OCCURRENCE.

The term "artesian" has been used with much confusion, but the best usage now restricts the word to those wells in which the water rises under pressure to a level higher than the water-bearing bed which yields it. Flowing wells are artesian wells in which the water rises above the level of the mouth of the well. Flowing wells, though not rare, are unusual enough to excite interest wherever they occur. The many conditions that produce artesian wells are fully discussed in Bulletin 319 and Water-Supply Paper 160 of the United States Geological Survey. The essential principle is that the water is under hydrostatic pressure and so tends to rise at any point where the pressure is relieved. The pressure is usually produced by the water percolating downward from an elevated source through an inclined porous stratum or channel, from which it can not escape. Therefore at levels lower than the source pressure is developed which may be sufficient to make the water rise only part way in the well that taps the aquifer, or which may be great enough to cause the water to rise to the surface and overflow. The difference in elevation between the mouth of the well and the source of the water, and also the grain of the aquifer determine the pressure of the water and, consequently, whether it rises to overflowing or not. In Kansas there are many flowing wells; those in Meade County, in Marion County, and in the southeastern corner of the State deserve special notice.

## MEADE ARTESIAN AREA.

The Meade area is an important one and has been carefully described by Erasmus Haworth, from whose report[1] most of the following description is taken. The Meade artesian area is located in the valley of Crooked Creek and extends from some 5 miles south of Meade nearly to Wilburn, so that it is about 20 miles long with a width in places of nearly 6 miles. The flowing wells have been sunk in an area of approximately 80 square miles. The area comprises a broad, flat valley, apparently almost level, with scarcely any irregularities of surface within it other than the small drainage channels tributary to Crooked Creek, which are 5 to 8 feet deep. On all sides and in every direction from the valley the ground is higher, so that there appears to be a natural wall around it. On the east and southeast the wall is from 50 to 100 feet high, with gently sloping sides, and the surface is largely covered with sand hills. On the north is a gentle rise toward Crooked Creek, producing a maximum elevation of about 75 feet between the main part of the valley and Crooked Creek itself. But at the northeast, toward Wilburn, the wall is much more abrupt, rising rapidly to a height of 100 to 140 feet. A few drainage channels originate in the high ground to the west and pass across the artesian valley to Crooked Creek, which is insignificant in appearance. It is generally but a few feet wide, is often dry, and can rarely be observed in the landscape farther than 100 feet away, so closely does it resemble an artificial ditch. It, as well as the other drainage channels, to a notable extent has also lifted its banks higher than the adjacent land. The uplands to the west of the artesian valley increase in height so rapidly that the plains to the north and northwest of Jasper, not over 10 miles away from the valley, are 2,700 feet high, while the general elevation of the artesian valley is between 2,400 and 2,500 feet. The Tertiary ground water in the high plains to the west is found at a depth of 125 to 150 feet, so that it must be 100 to 120 feet above the surface of the valley itself.

The artesian valley throughout is covered with Tertiary or Pleistocene deposits, the thickness of which is not known, for none of the artesian wells has passed through them. To the north, beyond Crooked Creek, the Benton group is exposed at the surface in a few places and has been reached by many of the wells. To the northeast,

[1] Water-Supply Paper U. S. Geol. Survey No. 6, 1897.

a few miles beyond Wilburn, the Dakota sandstone was reached by different wells. South of the valley the "Red Beds" appear at the surface, for the Benton and Dakota thin out to the south until they disappear. It is believed that the strata were here faulted so that the Meade valley was sunk to an unknown distance, at least 100 to 150 feet and that it has since been filled in to a considerable extent, probably in Pleistocene time. The materials shown in the borings from different wells over the valley can not be distinguished from the Tertiary deposits adjacent on all sides. They are composed of silt, clay, sand, and fine gravel, very irregularly mixed, so that there is no greater continuity of the bedding planes than may be found in the Tertiary deposits elsewhere. The "mortar beds" produced by the cementing of coarse sand seem to be wanting, but the finer sand and clay are in many places partially cemented by calcium carbonate, producing a certain degree of hardening similar to that observed in the mortar beds elsewhere.

The flowing wells come from Tertiary deposits or from Pleistocene beds composed of materials in every respect similar to the Tertiary deposits surrounding the valley upon all sides and seem sharply distinguished from the Dakota artesian wells known to exist to the north and northwest.

The flowing wells of Crooked Creek valley, it is believed, are fed by the ordinary ground water of the plains, which is slowly moving eastward on the inclined Cretaceous or "Red Beds" floor. Ordinarily this water is not confined between impervious layers, so that artesian conditions do not often develop, but as the Crooked Creek valley is approached the water in some way gently dips downward and passes under the clay beds near the west border of the flowing well area, perhaps rarely extending farther away than from 2 to 4 miles, and establishes a limited pressure.

Haworth made a few experiments to test the height to which water would rise in an open tube at the wells and found that the rise is only a few feet, perhaps always less than 20. The pressure which causes the flow from the wells, therefore, can not be due to the extra height the water has 10 miles to the west, otherwise the head would be much greater and the flow correspondingly stronger. The flow of the wells varies from almost nothing to 80 gallons a minute. It is impossible to give an average flow for the wells in the valley, but many exist which yield 30 gallons a minute.

The first flowing well in the valley was discovered in August, 1887, on the property of Benjamin Cox, about 300 feet southwest of a well in the SW. ¼ sec. 33, T. 30 S., R. 27 W., and was 142 feet deep.[1]

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[1] S. Ex. Doc. No. 41, pt. 2, Ap. 26, 52d Cong., 1st sess.

It appears to be the well in the NE. ¼ sec. 5, T. 31 S., R. 27 W.,[1] which, in October, 1907, was pointed out as the original well. It no longer flows, but water is easily raised from it by a pump. Apparently the well has become clogged with fine sand, for it yields plenty of sand with the water, and other wells nearby are flowing freely. The second well put down in the valley is located in the SW. ¼ sec. 33, T. 30 S., R. 27 W., and is still flowing strongly. On October 31, 1907, the temperature of many of the wells was taken with a thermometer and was found to vary between 14.5° and 16° C., 15° being the commonest. The shallowest flowing well in the valley is at the head of a draw in the SE. ¼ sec. 4, T. 30 S., R. 26 W., and is 65 feet deep. The deepest flowing well is in the NE. ¼ sec. 27, T. 31 S., R. 27 W., and is 320 feet deep. Most of the wells are 2 inches in diameter. Many of the wells are from 140 to 160 feet deep. In a general way the material passed through by all of the wells is alike, but in detail it is different. Each one passes through the surface soil, below which is encountered alterations of clay, sand, and soil. The sand is often cemented so that drillers speak of it as rock, but few of the cemented layers are more than 12 inches thick and many of them are not more than 6 inches. Apparently there is no particular stratum that must be reached in order to obtain flowing water. A mass of bluish clay frequently rests on top of a bed of uncemented sand stained yellow with iron rust, and this sand always contains water, generally the artesian water. The log of the well near the center of sec. 6, T. 31 S., R. 27 W., may be found on page 51, Water-Supply Paper of the United States Geological Survey No. 6,[2] and the logs of other wells in Senate Executive Document No. 41, part 2, Fifty-second Congress, first session, Appendix 26. Although flowing wells may be found almost anywhere over the valley, failures have been recorded. The northern and western sides of the valley are the most productive, though flowing wells are found all the way from Wilburn to the south of Meade. Some well sites on the west side of the valley are so high that the water does not overflow at the surface or does so very gently. East of Crooked Creek and south of Meade there are not many wells, and these do not flow strongly. The artesian area does not appear to extend much south of Spring Creek.

Springs exist at several places in the valley. One noted area is in the vicinity of Simm's ranch, 1½ miles north of Fowler. The springs are on the eastern side of Crooked Creek just along the border line between the valley proper and the higher lands to the east. The largest springs are located near the southeast valley line along the east side of the valley. If the valley has been dropped

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[1] S. Ex. Doc. No. 222, 51st Cong., 1st sess.

[2] This water-supply paper is no longer obtainable from the Survey, but it may be seen in the geologic library of Kansas University at Lawrence and in other large public libraries.

by faulting, the water-bearing sands in the valley are doubtless on a level with the "Red Beds" or the underlying Dakota sandstone on the east, which condition would cause springs to be more abundant along the east line than elsewhere. Farther south, along the western tributaries to Crooked Creek and in the valley of Crooked Creek itself, springs and seeps abound. The largest amount of spring water flows through Spring Creek, a stream about 3 miles south of Meade. Springs are abundant throughout almost the entire length of this stream but are particularly so in sec. 21, where most beautiful springs exist. At one place within an area of not more than 10 square rods the cold, clear water comes bursting forth from under the "mortar beds" bluff, forming a stream like a mill race. An approximate measurement of the run-off from this one area gave 3 second-feet. South from Spring Creek the next most important tributary from the west is Stump Arroyo, a stream along which springs are numerous, but which does not carry nearly as much water as Spring Creek. All these springs are connected with the artesian area to the north.

The water obtained from the springs and flowing wells is largely used for irrigation. At many of the ranch houses ponds or tanks fed by the flowing water are also used for fish. Many of the wells are left flowing and the water is allowed to waste without any attempt being made to utilize it.

The whole artesian valley is supplied with the ordinary ground water, which is found at 5 to 15 feet below the surface. Its abundance is not known, for no one cares to use it. As it has no artesian properties, it appears to be sharply distinguished from the deeper-lying water, though it must be admitted that the reason for the lack of connection is not clear.

## ARTESIAN WATER OF DICKINSON COUNTY.

At Herington, in Dickinson County, in the course of prospecting for a suitable city water supply, some very gently flowing wells were located southwest of the city. The source of this water is not apparent. It may be that the water makes its way westward along the surface of the Cottonwood limestone, which outcrops to the east of Herington in Lyon and Wabaunsee counties and dips to the west beneath Morris County toward Herington. The discovery of the flowing wells is interesting, but the water is much too highly mineralized for it to be of economic importance.

## ARTESIAN WATER FROM THE OZARK DOME.

Fort Scott, Girard, Pittsburg, Weir, Cherokee, Columbus, Chetopa, and other cities in the southeastern corner of the State have deep wells which are highly esteemed. The water is usually sulphosaline in character, is reached at a depth of several hundred feet, is artesian or flowing, and is believed to be derived from the Ozark uplift, which occupies the southern part of Missouri, the northern part of Arkansas, the northeastern corner of Oklahoma, and a bit of the southeastern corner of Kansas, being bounded on the north by Missouri River, on the northeast by Mississippi River, on the southeast by the upper portion of St. Francis River and by Black River, on the south by Arkansas River, and on the west by Neosho and Spring rivers. The area is elliptical and its axis is a curved line which extends northeastward through Missouri from the extreme northwestern corner of Arkansas through Aurora, Springfield, Marshfield, and Salem to the St. Francis Mountains in Iron County. The rivers which drain the area have a radial arrangement, heading along the axis of the dome and running therefrom toward all points of the compass. It is on the northwestern slope that the Galena-Joplin mining district is situated. Center Creek, Turkey Creek, Shoal Creek, and Spring River carry off the surface drainage, but there is a large permanent body of water located beneath the surface which is slowly making its way westward. Its source is somewhat uncertain. H. F. Bain believes it comes from underlying Silurian rocks which collect the water on their outcrop near Cedar Gap in Wright County, Mo., and which, dipping to the west and being overlain and underlain by impermeable rocks, carry the water westward beneath younger formation to the mining district.[1]

Erasmus Haworth contends that the Cedar Gap catchment area is too small to supply all of the water and that the prevailing ground water throughout the mining area of the Galena-Joplin district is surface water, probably more than 90 per cent of it having fallen as rain farther west than the surface exposure of Silurian rocks in the Ozark area. This water, he holds, has worked its way downward through various openings in the Mississippian Burlington limestone and is augmented by an unknown but relatively small amount of water which may work its way upward from the underlying Silurian rocks. These waters mingle and become as one body, making it impracticable to separate them from each other in effect and in their influence. This water which is slowly moving down the northwest slope of the Ozark dome is believed to be the source of the artesian waters of Bourbon, Crawford, Cherokee, and Labette counties, Kans., though the artesian effect in Kansas is not as great as might be expected from the fact that the general level of the Ozark dome is 1,500 feet or more, while that of the top of the wells is usually only about 900 feet, never over 1,000 feet. At Joplin, Empire, Columbus, Cherryvale, Weir, and Pittsburg there are many wells drilled into the Silurian sandstone, but the pressure is not sufficient

[1] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 92–94.

to bring the water to the surface. If there was not some vent giving relief to water starting westward from Cedar Gap, the pressure would certainly be much greater than it is. Probably it is through crevices of the badly fractured Mississippian rocks which overlie the Silurian that the pressure of the water contained within the latter formations is relieved. It seems likely, too, that through these same crevices the rainfall which comes down on the Mississippian—the surface rock west of Cedar Gap—works its way down to the great body of ground water.[1]

## DEPOSITS NOTABLY AFFECTING QUALITY OF WATER.

### SALT.[2]

Salt is found over a large part of the State of Kansas, either at the surface or within easy drilling distance. A very important salt area lies near the middle of the State, extending entirely across from the north line to the south and beyond into Oklahoma. The salt occurs (1) as brines in salt marshes, which by evaporation in the dry season leave salt on the surface, producing the so-called salt plains; and (2) as rock salt, which is found beneath the surface. In the eastern part of the State the shales belonging to the Permian (?) and Pennsylvanian series contain so much salt that the water obtained from them by means of deep wells is strongly saline.

The salt marshes are found in a zone trending a little east of north and west of south, reaching from Republic County on the north to Barber County on the south and to Cimarron River in Oklahoma. Robert Hay enumerates 12 salt marshes in Kansas, as follows:

1. The Tuthill Marsh, in southeastern Republic County, that drains into Republican River southeast of Lawrenceburg through Salt Creek.
2. Little Marsh, in northwestern Cloud County, that drains into Republican River through Buffalo Creek.
3. Jamestown Marsh, in Cloud, Republic, and Jewell counties, that drains into Republican River through Buffalo Creek.
4. A marsh on Plum Creek in Mitchell County, 4 miles northwest of Beloit, that drains into Solomon River.
5. Great Marsh, on Salt Creek, in Mitchell County, that drains into Solomon River.
6. A smaller marsh on Salt Creek in Mitchell County, northwest of number 5, that drains into Solomon River.

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[1] Kansas Univ. Geol. Survey, pp. 57–68, 93–103, 125.

[2] Prepared from articles by:

Haworth, Erasmus, Mineral resources of Kansas, 1898, Kansas Univ. Geol. Survey, pp. 86–89.

Kirk, M. Z., Mineral resources of Kansas, 1898, Kansas Univ. Geol. Survey, pp. 69–85, 98–123.

Hay, Robert, Sixth Bienn. Rept. Kansas State Board Agr., 1889, pp. 192–204; Seventh Bienn. Rept. Kansas State Board Agr., 1891, pp. 83–94; Eighth Bienn. Rept. Kansas State Board Agr., 1893, pp. 137–142.

Bailey, E. H. S., Eighth Bienn. Rept. Kansas State Board Agr., 1893, pp. 167–180.

7. A marsh on Rattlesnake Creek, in Lincoln County, that drains into Solomon River through Salt Creek.

8. A marsh in Lincoln County, at the junction of Prosser and Battle creeks, which drains into Rattlesnake Creek, and thence by way of Salt Creek into Solomon River.

9. Big Marsh in Stafford County.

10. Little Marsh, southeast from No. 9 in Stafford County. Rattlesnake Creek, which empties into Arkansas River at Alden, passes between Nos. 9 and 10, absorbs salt and becomes brackish, but does not drain either of them.

11. Geuda Springs, in Sumner County, which are drained by Salt Creek into Arkansas River.

12. A marsh in Sumner County northwest of Geuda Springs; this marsh drains into Arkansas River.

A brief description of a few of these marshes will serve to give a correct conception of them all. Republic County has two marshes, Tuthill Marsh and Jamestown Marsh. The Tuthill was one of the most important marshes in pioneer times. In autumn the water is generally nearly all evaporated, and the edges of the marsh are dry and covered by a hard, thin scale of impure salt. Toward the center of the marsh the surface is more moist and the scale of salt less thick and solid. Nearer the center are found numerous pools of clear, briny water. During rainy seasons water collects over the marsh to a depth of a foot or more, coming from ravines in neighboring hillsides and from numerous seeping springs near the edge of the marsh. This marsh and other similar marshes of the State were of great value to hunters in early times. They came here to "jerk" their buffalo meat. When they were in too great haste to wait to evaporate the brine and get the crystallized salt, they dipped the meat and hides into the pool of strongest brine and then dried them in the sunshine or by the fire. When a considerable quantity of meat was to be "jerked," the meat was cut into long strips and dipped in brine that was boiled in kettles over a fire of buffalo chips. It was then laid out to dry in the sunshine or on a lattice work made of green poles supported on four posts with a fire under it. In this way 200 or 300 pounds could be cured in five or six hours. Mr. Tuthill (Tuttle?), for whose family the marsh was named, was the first salt manufacturer of the State. In the early sixties he made salt and hauled it to Manhattan, where it brought as high as 10 cents a pound.

In Mitchell County salt springs and marshes are abundant on Salt Creek in the southern portion, while a few are found on Carr and Hard Scrabble creeks. The Waconda Spring is heavily impregnated with salt.[1]

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[1] Sixth Bienn. Rept. State Board Agr., 1887–88, p. 315.

In the northern part of Mitchell County on Plum Creek is a small marsh scarcely more than a small lick. Its banks have become tramped and there is but slight efflorescence on a very small area—less than an acre—though signs of it show at intervals farther down the valley.

In Lincoln County, besides the marshes mentioned by Hay, saline springs are abundant along Saline River and Spillman Creek,[1] a tributary of that stream.

The two marshes in Stafford County are known as Big Marsh and Little Marsh. These marshes were not only used for curing venison, but a little salt plant was erected and a considerable quantity of salt was made about 1878. The product came from a spring at the south part of the Big Marsh and was sold in Great Bend as early as 1867.

In Reno County, Peace Creek, which enters Arkansas River near Sterling, drains a small salt marsh.

In the southeastern part of Greenwood County in Salt Springs Township there are salt springs from which salt was at one time manufactured. These springs discharge into Fall River.[2]

The three saline reserves, East, Middle, and West, in Oklahoma, are closely allied to the salt marshes of Kansas. The East Saline Reserve is located on Salt Fork of Arkansas River in Alfalfa County, Okla., a little below the mouth of Medicine Lodge River. This marsh is larger than any in Kansas, extending 14 miles from north to south and 8 miles from east to west at the widest point. It is locally known as the Great Salt Plain.

Middle Saline Reserve is in Woods, Woodward, and Harper counties, Okla., on Cimarron River at the mouth of Buffalo Creek. The marsh covers a large part of two sections and is the most valuable salt plain of the whole region. On the south side of Buffalo Creek are some strong salt springs, and in numerous places the strong brine bursts forth and runs into a second little stream or disappears in the sand. In dry weather the brines from the springs are so concentrated that they deposit rock salt over the whole surface of the marsh. The wind-blown sand soon covers the salt to a depth of several inches or even feet. In early times the Indians and, later, the stockmen came here and hauled away the salt in large quantities, taking it to various places in Oklahoma and Kansas.

West Saline Reserve is a few miles above Middle Reserve on the Cimarron in Woods and Harper counties, Okla. It is small and of minor importance.

The salt marshes in the northern part of Kansas and possibly as far south as Stafford County obtain their salt from the saliferous shales of the Dakota sandstone. On account of their highly salty

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[1] Sixth Bienn. Rept. Kansas State Board Agr., 1887-88, p. 270. [2] Idem, p. 193.

character, these shales are particularly subject to erosion and have been important factors in the production of many of the low marshy areas so common to the northern part of the State. An extreme example of the result produced by the resolution of the shales is the great basin known as the Cheyenne Bottoms,[1] a few miles north of Great Bend. The salt marshes represent in most cases, first, a low level area produced by erosion of these shales and, second, a mass of brine which has received its salt by the rain water leaching the latter from adjacent shales to the west. In some places the brine seems to reach the surface in the form of deep-seated springs, while elsewhere it is by ordinary hillside springs. It is quite possible the other horisons in the Dakota assist in supplying salt for the salt marshes, as they are known to be slightly saline, but the saliferous shale beds are the principal producers. The source of the salt in the Stafford County marshes may be somewhat doubtful. The surface of the country here is so mantled by the Tertiary deposits and alluvial sands and gravel that it is difficult to make accurate observations regarding conditions beneath them. The "Red Beds" are known to be saline throughout their whole thickness. The salt of the marshes in Cimarron River area and the Salt Fork area comes from the "Red Beds," being produced by rain waters leaching the salt from beds near the surface in the gradual process of erosion. The "Red Beds" are known to extend northward under the Tertiary deposits to a point beyond Stafford County. It is therefore somewhat difficult to decide from which source, the "Red Beds" or the shales of the Dakota, the Stafford marshes are supplied.

From the earliest settlement of the State numerous briny wells have been found throughout the rocks of the Pennsylvanian series. None of these have been at any time of great importance, although some salt has been produced from those at Alma, St. Marys, Osawatomie, and Junction. The only brine wells that were ever commercially successful for a considerable period were those at Solomon, where for some years salt was made by the solar process. At present the plant is abandoned.

Rock salt was discovered in the fall of 1887 and during 1888 at Ellsworth, Lyons, Hutchinson, Great Bend, Kanopolis, Pratt, Nickerson, Sterling, Kingman, Anthony, Wellington, Rago, and Arlington. In 1889 it was found at Wilson and in 1895 at Little River. In several of these places the salt bed is 300 to 400 feet thick. These immense salt deposits were formed by the evaporation of bodies of salt water. They belong to the Permian (?) series and occupy a position intermediate between the Marion formation below and the Wellington shale above. The gypsum of Kansas usually underlies the salt and was probably precipitated from the same bodies of water

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[1] A description of the Cheyenne Bottoms appears in vol. 2, Kansas Univ. Geol. Survey, pp. 42–45.

by evaporation prior to the deposition of the salt. The relations of the gypsum and salt deposits to each other in Kansas is an interesting matter, but it is not thought pertinent to this description of the salt deposits. Papers by Robert Hay in the Sixth, Seventh, and Eighth biennial reports of the Kansas State Board of Agriculture, and one by Erasmus Haworth in the Mineral Resources of Kansas for 1898, Kansas University Geological Survey, discuss the subject thoroughly.

A peculiar salt pool at Meade is described by Robert Hay. It seems that in 1878 the surface of the ground suddenly sank in a circular area over 150 feet in diameter and that a depression with steep sides, having in the bottom a pool of water 50 feet deep, was formed. From the prairie to the surface of the water is about 20 feet. The water had a high temperature at the time, but has since cooled. In the interval since its formation the pool has diminished in depth from the accumulation of débris from its sides.

Many flowing salt wells in the State contribute to the salt content of the streams. The wells at Larned and Great Bend, which flow into Arkansas River, may be noted as examples. Analyses of Kansas salt by E. H. S. Bailey [1] show it to be very pure. Gypsum is the most troublesome impurity to salt manufacturers. In making salt by the pan process the gypsum is deposited on the pan and is somewhat difficult and expensive to remove. Moreover, any residuum of gypsum in the salt prepared for commerce makes it cake and harden. In some instances the undesirability of gypsum limits the scale of operation of those plants which take the salt from the ground by forcing fresh water into the salt and then withdrawing it, because waters containing much gypsum are unfit for the purpose and so it may be necessary to reject an abundant supply of water carrying gypsum in solution in favor of an inadequate one that is free from it. The production of salt in Kansas for the year 1908 was 2,588,814 barrels and was valued at $882,984. The production from 1888 to 1908 was 34,050,724 barrels and was valued at $11,989,822.[2]

## GYPSUM.[3]

The Kansas gypsum deposits of economic value form a belt trending northeast and southwest across the State. The belt of exposed rock varies in width from 5 miles at the north to 25 miles in the central part, and to 140 miles near the southern line, with a length of 230 miles.

This area is naturally divided into three districts, which are named from the important centers of manufacture: The northern or Blue Rapids area, in Marshall County; the central or Gypsum City area,

[1] Eighth Bienn. Report Kansas State Board Agr., 1893, pp. 167–180.
[2] Mineral Resources U. S., for 1898, 1900, 1908, U. S. Geol. Survey.
[3] Abstracted from Kansas Univ. Geol. Survey, vol. 5, p. 31.

in Dickinson and Saline counties; and the southern or Medicine Lodge area, in Barber and Comanche counties. These areas appear to be separate, but careful mapping shows a number of isolated intermediate deposits, which serve to connect the northern and central areas, and indicate connection between the central and southern areas These connecting links are found near Randolph and in the reservoir excavation at Manhattan, in Riley County; at Longford, in the southern part of Clay County; and near Manchester, in the northern part of Dickinson County.

From an examination of a map of west central United States with the gypsum deposits indicated thereon, it will be seen that if the northeast line of the Kansas deposits is extended it will strike the Fort Dodge area in Iowa, and if it is continued to the southwest it will strike the extensive deposits of Canadian River in Oklahoma and those of Texas.

## QUALITY OF UNDERGROUND WATERS, BY COUNTIES.

For the convenience of the greater number of users of this report the information that has been gathered concerning the quality of underground waters has been assembled under county headings, but it is believed that this arbitrary grouping will not seriously inconvenience those who, in the course of special examinations, have to make a more natural arrangement of the analyses, as, for instance, to group together the wells in the fluviatile deposits of a river. Unless otherwise stated, all the assays herein reported were made by H. N. Parker, of the United States Geological Survey.

### ALLEN COUNTY.

As Allen County is underlain by Pennsylvanian rocks the prospect of discovering soft waters is not good. The only analysis presented in the accompanying table (No. 1) is that of the waters of a deep well in Iola, which is very salty. Assay 3, Table 1, shows the results of a test of the water of a deep well at Humboldt; the water is very hard and contains considerable common salt. Assays 1, 2, and 4 are tests of shallow well waters. The first and last of these assays indicate high permanent hardness; the second shows very low permanent and high temporary hardness. Assays 5 and 6 are tests of spring waters, both of which have marked temporary and considerable permanent hardness.

TABLE 1.—*Analysis and assays of underground waters of Allen County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | |
| 1 | 1876 | Iola well[a] | 720 | W. R. Kedzie. | 10 | 21 | 256 | 104 | (Na) 6,580<br>(K) 192 | 10,321 |

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate. ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | | |
| 1 | 1905. July 21 | Humboldt, well at northwest city limits. | 14 | Edward Bartow | 0.0 | 0.0 | 365 | 72 | 49 |
| 2 | ...do..... | Humboldt, well at southeast city limits. | 60 | .....do | Trace. | .0 | 486 | Trace. | 99 |
| 3 | ...do..... | Humboldt, well | 214 | .....do | .0 | .0 | 461 | 539 | 224 |
| 4 | ...do..... | Humboldt, upland well 4 miles south of city. | 20 | .....do | .0 | .0 | 288 | 150 | 258 |
| 5 | ...do..... | Humboldt, spring west side of river below dam. | | .....do | .0 | .0 | 330 | 47 | 12 |
| 6 | ...do..... | Humboldt, spring south of Coal Creek. | | .....do | .5 | .0 | 304 | 36 | 14 |
| 7 | ...do..... | Iola, well near Atchison, Topeka and Santa Fe Ry. depot. | 27 | .....do | .0 | .0 | 396 | 276 | 69 |
| 8 | 1907. Apr. 25 | Iola, well at 702 South Chestnut Street. | 25 | | .5 | .0 | 332 | ([b]) | 146 |
| 9 | ...do..... | Iola, well at 828 North Street. | 40 | | .0 | .0 | 200 | 202 | 34 |
| 10 | 1905. June 30 | La Harpe, well one-half mile south and three-fourths mile west of city. | 15 | Edward Bartow | .0 | .0 | 489 | ([b]) | 40 |

[a] Kansas Univ. Geol. Survey, vol. 7. [b] $SO_4$ greater than 626.

## ANDERSON COUNTY.

As Anderson County is underlain by Pennsylvanian rocks, soft waters are not common. No complete analyses are presented. Of the five water assays (Table 2), one is of a deep well water, one of a spring water, and the rest are of waters from wells 35 feet or less deep. The deep well water is very high in chlorides but is not notably hard. The water from the 16-foot well at Harris is soft, and that from the 15-foot well at Greeley has little permanent hardness, but the water from the 35-foot well at Greeley and that from the spring at Garnett have great permanent hardness.

TABLE 2.—*Assays of underground waters from Anderson County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1905. June 23 | Garnett, deep well in southeast part of city. | ........ | Edward Bartow... | 33.0 | 0.0 | 305 | Trace. | 27,916 |
| 2 | ...do.... | Garnett, spring at creamery on Sixth Street. | ........ | .....do.............. | ...... | .0 | 341 | 256 | 61 |
| 3 | June 22 | Harris, well 2 miles north and 3 miles east of city. | 16 | .....do............ | .0 | .0 | 123 | Trace. | 108 |
| 4 | ...do.... | Greeley, well half mile north and 3 miles west of city. | 35 | .....do............. | .0 | .0 | 180 | 150 | 147 |
| 5 | June 23 | Greeley, well 1 mile north and one-half mile west of city. | 15 | .....do............. | .0 | .0 | 377 | Trace. | 15 |

ATCHISON COUNTY.

As Atchison County is underlain by Pennsylvanian rocks, most of the waters are hard, though there may be soft waters in the glacial deposits. The analyses (Table 3) show that the waters from two deep wells and a shallow one in Atchison are very high in chlorides and are very hard. The assays (Table 3) are tests of other Atchison well waters; these waters also are hard and are much lower in chlorides than those well waters that were tested by analysis.

TABLE 3.—*Analyses and assays of underground waters in Atchison County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | 1907. Apr. 2 | Atchison, well of A. B. C. laundry. | 63 | Kennicott Water Softener Co. | 28 | 2.7 | 130 | 62 | 692 | ..... | 474 | 165 | 1,072 |
| 2 | 1900. Summer. | Atchison, diamond-drill prospect boring. | a1,353 | E. H. S. Bailey and F. B. Porter. | 36 | 62.0 | 570 | 123 | (Na) 9,801<br>Trace (K) | .... | 2,408 | 19 | 15,066 |
| 3 | .......... | Atchison,[b] Becker's mineral well.[a] | 125 | E. B. Knerr. | 18 | 42.0 | 420 | 310 | 10,100(Na)<br>36 (K) | 1671 | ..... | 1,109 | 15,550 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. July 18 | Atchison, well of Cain Milling Co.[c] | 60 | ............... | .... | 10.0 | ... | ... | ........... | .0 | 358 | 98 | 282 |
| 2 | ...do.... | Atchison, well of Luken's Milling Co.[d] | 46 | ............... | .... | 24.0 | ... | ... | ........... | .0 | 319 | 186 | 146 |

[a] Kansas Univ. Geol. Survey, vol. 7.
[b] In valley of White Clay Creek.
[c] Put down in 1893.
[d] Put down in 1902.

## BARBER COUNTY.

Most of Barber County is underlain by Permian (?) rocks, but in the northern part and in a narrow arm indenting the western side the Comanche series and Tertiary deposits appear. The prospect of finding soft water outside of the area of Tertiary deposits is poor, for the Comanche series covers such a restricted area that it is an unimportant water-bearing terrane, and the Permian (?) rocks yield in most places highly mineralized waters. All of the waters tested come from the Permian (?) rocks and are very hard. The results of tests of underground waters in this county are shown by the analyses and assays in Table 4.

TABLE 4.—*Analyses and assays of underground waters, Barber County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1902. Oct. 21 | Kiowa, surface well. | ... | Atchison, Topeka & Santa Fe Ry. | 7.2 | 3.8 | 91 | 100 | 86 | 242 | .... | 314 | 66 | .... | ..... |
| 2 | 1903. Feb. 7 | Kiowa, city well... | ... | .....do........... | 12 | .... | 298 | 104 | 87 | 120 | .... | 979 | 99 | 214 | 1,917 |
| 3 | Apr. 24 | Kiowa, test well south of tank. | ... | .....do........... | 15 | .... | 100 | 20 | 32 | 141 | .... | 98 | 46 | 19 | 471 |
| 4 | Sept. 4 | Kiowa, Atchison, Topeka & Santa Fe Ry. well. | ... | .....do........... | .... | 2.4 | 142 | 117 | 129 | 106 | .... | 654 | 184 | 171 | 1,583 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Jan. 21 | Kiowa, city well... | ... | .................. | .... | .0 | ... | ... | .... | .0 | 260 | (a) | 130 | .... | ..... |
| 2 | 1908. Jan. 8 | Medicine Lodge, well of Thos. Murphy. | 96 | .................. | .... | Tr. | ... | ... | .... | .0 | 214 | (a) | 41 | .... | ..... |

a $SO_4$ greater than 626.

## BARTON COUNTY.[1]

The southern half of Barton County is underlain by the Dakota sandstone and the northern half by shales belonging to the Benton group. Along Arkansas Valley the Dakota sandstone is covered by a considerable thickness of alluvial materials, and also, on the south side of the river, by large deposits of dune sands.

The Dakota sandstone is penetrated by numerous wells, to most of which it furnishes satisfactory supplies of water. Some of these wells begin in the sandstone and are bored or dug into its lower beds. The

[1] Abstracted in large part from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 290.

wells in the highlands in the north part of the county pass through a greater or less thickness of shales of the Benton and thence into the sandstone. A well 245 feet deep, 8 miles north and 2 miles west of Hoisington, penetrates 222 feet of shale before reaching the sand rock, where it obtains a large supply of water, which rises to within 212 feet of the surface. Southwest of Galatia the shale is 260 feet thick and the underlying sandstone furnishes a good supply of water, which rises to within 236 feet of the surface. At Olmitz a well 202 feet deep passes through the shales of the Benton into the sandstone and obtains a supply of very soft water, which rises to within 142 feet of the surface. A well 3 miles north of Verbeck has a depth of 244 feet, and the water rises to within 144 feet of the surface.

These representative wells indicate that satisfactory supplies of water are obtainable from the Dakota sandstone through most of the north portion of the county, but that there are no prospects for flows. Several wells about Roberts, from 175 to 300 feet deep, obtain only salty or brackish water, of which the source is probably the transition salty series at the base of the Benton shales.

In the southern part of the county the wells are shallower and mostly successful. The only unsuccessful well which has been reported is one in sec. 17, T. 18 S., R. 12 W., which penetrated the Dakota sandstone 200 feet without obtaining a water supply. Four miles northeast of Great Bend a deep well was sunk some years ago to a depth of 1,365 feet to test the water supplies of the formations underlying the Dakota sandstone. Flowing water was obtained at 344 feet and at somewhat over 700 feet. The first water is still flowing at the rate of 10 gallons per minute, but is too salty to be of any use. From 1,202 to 1,365 feet a large amount of rock salt was penetrated, and some of the overlying beds were highly gypsiferous. The following record is given:

*Record of deep well at Great Bend.*

| | Feet. |
|---|---|
| Surface materials | 0– 60 |
| Red sandstone | 60– 75 |
| Red shale | 75– 140 |
| Blue shale | 140– 155 |
| Sandstone, brown near top, hard near bottom | 155– 255 |
| Shale | 255– 258 |
| Hard sandstone | 258– 275 |
| Conglomerate water | 275– 310 |
| Gray sandstone, artesian flow of salt water | 310– 360 |
| Gray sand and shales; salt water | 360– 400 |
| Red shale | 400– 420 |
| Blue shale | 420– 425 |
| Sandstone | 425– 475 |
| Red shale with some sandstone | 475–1,110 |
| Blue shale | 1,110–1,240 |
| Salt and shale | 1,240–1,365 |

This well was mainly in the Permian rocks, and it is doubtful if the red sandstone from 60 to 75 feet belongs in the Dakota.

The analyses and assays recorded in Table 5 were made on waters derived from several different water-bearing formations. The analyses of the water taken from the wells at Ellinwood and Great Bend show the characters of the waters derived from the fluviatile deposits of Arkansas River, which are characteristically high in sodium and sulphates. The variations in the constituents of the water of the Great Bend Water Supply Co. are noticeable, but they may be in part accounted for by the fact that the supply is derived from several wells, one of which—a shallow one—was abandoned about 1902. Analysis 8 is of the water of the flowing salt well. Information is lacking as to the sources of the waters in the wells at Albert and Hoisington. A calcic alkaline water from the well at Albert is shown by analysis 1.

The assays are very interesting. Nos. 1, 2, and 5 show the results of tests of shallow-well waters. They indicate high temporary hardness, but the permanent hardness is not great. Nos. 3, 4, 6, 7, and 8 are all tests of water from the Dakota sandstone and show very nicely the different degrees of mineralization that obtains in waters from the upper part of the formation. Nos. 3 and 4 show waters low in chlorides and sulphates. These waters, except for the temporary hardness, which is not great for the region, are very satisfactory for domestic and industrial use. Nos. 6, 7, and 8 are tests of waters that are successively higher in sulphates and chlorides. Their use in the household would cause large soap consumption and in boilers they might be expected to form scale rapidly. They could not be softened without increasing their tendency to foam. These three waters are derived from wells in the gypsiferous and saliferous shales of the Dakota. Probably by casing off the water from these shales and sinking the wells deeper into the Dakota good water could be obtained.

Tests of waters from shallow wells in the Cheyenne Bottoms, an alkali basin of over 30,000 acres in area, which receives the waters of Blood Creek and which has only a partial outlet, are recorded in assays 9–13, inclusive. It is believed that the evaporation in the basin is very intense and that thereby the waters become concentrated. The water of the well at the St. Regis Club House is particularly highly mineralized, and it is to be hoped that a complete mineral analysis of water from this well will sometime be made. Assays 14 and 15 are tests of shallow wells in the fluviatile deposits of Arkansas River.

TABLE 5.—*Analyses and assays of well waters from Barton County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| | 1902 | | | | | | | | | | | | | | | |
| 1 | Oct. 15 | Albert, surface well | ........ | Kennicott Water Softener Co. | 38 | 6 | 98 | 18 | 31 | 186 | ........ | 50 | ........ | 18 | ........ | ........ |
| 2 | Oct. 22 | Ellinwood, surface well | ........ | Atchison, Topeka & Santa Fe Ry. | 21 | Tr. | 115 | 24 | 92 | 63 | ........ | 355 | ........ | 79 | ........ | ........ |
| 3 | Oct. 15 | Great Bend, surface well | ........ | ....do | 19 | 1.3 | 108 | 27 | 94 | 93 | ........ | 314 | ........ | 73 | ........ | ........ |
| | 1903 | | | | | | | | | | | | | | | |
| 4 | June 31 | Great Bend, waterworks, wells | ........ | ....do | 8.6 | ...... | 106 | 43 | 108 | 93 | ........ | 346 | ........ | 115 | 125 | 952 |
| 5 | Feb. 16 | ....do | ........ | ....do | 6.8 | ...... | 86 | 16 | 41 | 85 | ........ | 181 | ........ | 29 | 44 | 490 |
| 6 | May 29 | ....do | ........ | ....do | 14 | ...... | 55 | 36 | 173 | 91 | ........ | 406 | ........ | 60 | 132 | 967 |
| | 1907 | | | | | | | | | | | | | | | |
| 7 | Aug. 31 | ....do | ........ | F. W. Bushong [a] | 20 | 3 | 102 | 23 | 70 | .0 | 198 | 216 | 2.6 | 50 | ........ | 572 |
| 8 | ........ | Great Bend, flowing salt well [b] | 1,100 | E. H. S. Bailey | 40 | ...... | 662 | 692 | 22,454 | ........ | ........ | 4,788 | ........ | 33,059 | ........ | ........ |
| 9 | ........ | Hoisington, 4 wells | 70–73 | Missouri Pacific Ry | 24 | 2.2 | 110 | 15 | 29 | 144 | ........ | 101 | ........ | 38 | 28 | 492 |
| | | ASSAYS. | | | | | | | | | | | | | | |
| | 1907 | | | | | | | | | | | | | | | |
| 1 | Dec. 17 | Hoisington, city waterworks well | 55 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 329 | Trace. | ........ | 67 | ........ | ........ |
| 2 | Dec. 26 | Hoisington, well of Hoisington Light & Power Co., block 42, Railroad Street. | 63 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 248 | 50 | ........ | 83 | ........ | ........ |
| 3 | ...do | Hoisington, well of H. Wildgen, block 35, lot 4. | 60 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 302 | Trace. | ........ | 52 | ........ | ........ |
| 4 | ...do | Hoisington, well of J. B. Prose, block 4, lot 11, West Addition. [c] | 66 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 313 | Trace. | ........ | 30 | ........ | ........ |
| 5 | ...do | Hoisington, well of J. B. Morgan, NE. ¼ sec. 13, T. 17 S., R. 14 W. | 175 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 363 | Trace. | ........ | 30 | ........ | ........ |
| 6 | ...do | Hoisington, well of D. W. Humphrey, SW. ¼ sec. 4, T. 17 S., R. 13 W. | 30–40 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 418 | 79 | ........ | 30 | ........ | ........ |
| 7 | ...do | Hoisington, well of J. V. Susank, SE. ¼ sec. 31, T. 15 S., R. 13 W. | 330 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 408 | 98 | ........ | 448 | ........ | ........ |
| 8 | ...do | Hoisington, well of D. W. Humphrey, SE. ¼ sec. 6, T. 17 S., R. 13 W. | 174 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 456 | 150 | ........ | 600 | ........ | ........ |
| 9 | ...do | Hoisington, well of Anthony Susank, sec. 19, T. 16 S., R. 13 W. | 280 | ........ | ........ | Tr. | ...... | ...... | ........ | .0 | 328 | 164 | ........ | 2,043 | ........ | ........ |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Dec. 24 | Hoisington, well of John Harmison in Cheyenne Basin, SE. ¼ sec. 10, T. 18 S., R. 13 W. | 30 | | | .0 | | | | .0 | 409 | 47 | | 166 | | |
| 11 | ...do..... | Hoisington, well of John Hall in Cheyenne Basin, NW. ¼ sec. 10, T. 18 S., R. 13 W. | 14 | | | .0 | | | | .0 | 475 | 132 | | 680 | | |
| 12 | ...do..... | Hoisington, well of J. B. Prose in Cheyenne Basin, NW. ¼ sec. 24, T. 18 S., R. 13 W. | 21 | | | .0 | | | | .0 | 322 | 276 | | 845 | | |
| 13 | ...do..... | Hoisington, well of Gus Rowe in Cheyenne Basin, NW. ¼ sec. 23, T. 18 S., R. 13 W. | 20 | | | .0 | | | | .0 | 382 | 405 | | 156 | | |
| 14 | ...do..... | Hoisington, well at St. Regis Club House of Great Bend Sportsmen's Association in Cheyenne Basin, SW. ¼ sec. 12, T. 18 S., R. 13 W. | | | | .0 | | | | .0 | 670 | (*d*) | | 3,124 | | |
| 15 | Dec. 9 | Great Bend, well of Atchison, Topeka & Santa Fe Ry. | 10 | | | .0 | | | | .0 | 262 | 574 | | 85 | | |
| 16 | | Great Bend, shallow well of Great Bend Water Co. | 27 | | | .0 | | | | .0 | 214 | 197 | | 40 | | |

*a* Analysis made at the laboratories of the University of Kansas.
*b* Kansas Univ. Geol. Survey, vol. 7.
*c* In Dakota sandstone. Water rises within 22 feet of surface.
*d* $SO_4$ greater than 626.

## BOURBON COUNTY.

As Bourbon County is underlain by Pennsylvanian rocks hard waters are to be expected.

The Fort Scott artesian well is 510 feet deep. At 380 feet salt water was struck, which rose to within 18 feet of the mouth of the well; at 510 feet water of a different character was found, and the well became a flowing one. The deeper water is probably derived from the Ozark dome. The water is sulphosaline in character. The well of the Hotel Goodlander is 700 feet deep and the water is of a sulphomagnesian character.

Assays 3, 4, and 5, Table 6, represent tests of deep well waters. The waters have a sulphur odor, high chlorides, and high temporary hardness. Marked permanent hardness is shown by assay 5, while assays 3 and 4 indicate less. Assay 8, which was made on water from a prospect hole 500 feet deep, shows the chlorides and temporary hardness to be greater than in any other well water in the county that was tested; the softest water is indicated by assay 10. Assays 1, 2, 6, 7, 9, 11, and 12 are tests of waters from shallow wells; all of the waters are hard, but that of which assay 12 is a test is decidedly the hardest.

TABLE 6.—*Analyses and assays of underground waters, Bourbon County.*

[Parts per million.]

| No. | Source. | Depth (feet). | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | ANALYSES. | | | | | | | | |
| 1 | Fort Scott,[a] Fort Scott artesian.. | [b] 510 | 16 | 5.4 | 70 | 35 | (Na) 550<br>(K) Tr. | 10 | 937 |
| 2 | Fort Scott,[c] well south of Hotel Goodlander. | [b] 700 | 20 | 2.1 | 76 | 36 | (Na) 594<br>(K) 10 | 6.2 | 944 |

[a] Flowing well 621 feet deep; at 380 feet salt water was encountered, which rose to within 18 feet of surface; at 510 feet water of different composition was struck, which began flowing from well. Sample as analyzed probably is a mixture of waters at different depths. Slight odor of sulphureted hydrogen.

[b] Kansas Univ. Geol. Survey, vol. 7.

[c] Al, 7.6; $B_4O_7$, 11; S, 20.

TABLE 6.—*Analyses and assays of underground waters, Bourbon County*—Continued.

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | | |
| | 1905. | | | | | | | | |
| 1 | July 1 | Fort Scott, flowing well in northwestern part of city, between Mill Creek and Marmaton River. | ........ | ................. | 0.0 | 0.0 | 304 | 176 | 509 |
| 2 | July 29 | Fort Scott, well at Locust Street and Scott Avenue. | [a] 42 | ................. | .0 | .0 | 279 | 460 | 79 |
| 3 | ...do.... | Fort Scott, Kramer deep well.[b] | ........ | ................. | .0 | .0 | 427 | Tr. | 891 |
| 4 | July 27 | Fort Scott, Missouri Pacific Ry. well. | ........ | ................. | .0 | .0 | 481 | 40 | [c] 1,017 |
| 5 | ...do.... | Fort Scott, artesian well of Bridal Veil Park.[d] | ........ | ................. | .0 | .0 | 294 | 89 | 920 |
| 6 | ...do.... | Fort Scott, well of Henry Wagner, 3 miles west of city. | 40 | ................. | .0 | .0 | 370 | 65 | 14 |
| 7 | July 1 | Fulton, well at creamery. | 35-40 | ................. | 3.0 | .0 | 384 | 222 | 138 |
| 8 | ...do.... | Fulton, drilled well[e] | 500 | ................. | 2.5 | .0 | 582 | 47 | 1,630 |
| 9 | July 27 | Garland, shallow dug well. | ........ | Edward Bartow. | .0 | .0 | 156 | 229 | 34 |
| 10 | ...do.... | Garland, spring, 2 miles south and 3½ miles west of city. | ........ | .....do........... | .0 | .0 | 210 | 38 | 12 |
| 11 | ...do.... | Marmaton, dug well of J. Seaman. | 35 | ................. | .0 | .0 | 299 | 574 | 311 |
| 12 | ...do.... | Marmaton, drilled well of J. Pulling. | [f] 40 | ................. | .0 | .0 | 391 | 626 | 45 |

[a] Water from rock.
[b] Odor of sulphureted hydrogen. Water used at baths.
[c] Chlorine possibly high on account of presence of sulphides.
[d] Odor of sulphureted hydrogen.
[e] Drilled for oil; cased 40 feet; abandoned. Water rises to within 22 feet of surface.
[f] Water at 25 feet.

## BROWN COUNTY.

As Brown County is underlain by Pennsylvanian rocks prospects for soft waters are poor, but possibly soft waters may be found in the glacial deposits which are spread over this and adjoining counties.

The analysis and assay 4 (Table 7) represent tests of well waters in the valleys of Little Delaware and Mission creeks, and show that these two waters have considerable permanent hardness. The other assays are tests of waters that have very little permanent hardness and are believed to be derived from wells sunk in glacial deposits.

Table 7.—*Analysis and assays of underground waters in Brown County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | |
| 1 | 1908. September | Horton, well of Chicago, Rock Island & Pacific Ry. | 30 | Chicago, Rock Island & Pacific Ry. | [a]6.1 | 46 | 14 | 16 | 87 | 41 | 13 | 225 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$) | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1907. | | | | | | | |
| 1 | July 19 | Hiawatha, tap in Hotel Moreland, city water, 3 wells | 24, 30, 28 | 0.0 | 0.0 | 324 | Tr. | 10 |
| 2 | July 20 | Hiawatha, well of Barnum & Sutley on Iowa Street [b] | 40 | .0 | .0 | 332 | Tr. | 14 |
| 3 | July 20 | Hiawatha, well of Sally Wahlthall, on Delaware Street, between First and Second [c] | 90 | Tr. | .0 | 332 | Tr. | 34 |
| 4 | July 16 | Horton, well of Horton Light & Power Co. | ........ | .0 | .0 | 307 | 52 | 14 |
| 5 | July 20 | Reserve, well of H. B. Willard, sec. 1, T. 1 S., R. 16 E. | 50 | .0 | .0 | 263 | Tr. | 10 |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.
[b] Used for ice manufacture and for swimming pool.
[c] Well roars and becomes turbid on approach of a storm.

## BUTLER COUNTY.

The extreme eastern edge of Butler County is underlain by Pennsylvanian rocks, but elsewhere in the county the rocks belong to the Permian (?) series. The ground waters, therefore, may be expected to be hard and highly mineralized.

Table 8 shows the results of tests of well waters in the valley of Walnut River and its tributaries. These waters are shown to have high temporary and permanent hardness. The only assay is a test of the city water at Eldorado, which is hard.

TABLE 8.—*Analyses and assay of well waters in Butler County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1902. Oct. 22 | Augusta, well | ... | Atchison, Topeka & Santa Fe Ry. | 15 | 0.6 | 130 | 23 | .... | 170 | .... | 74 | 43 | .... | ..... |
| 2 | 1903. Oct. 21 | Augusta, Atchison, Topeka & Santa Fe Ry. well. | ... | do. | 19 | .... | 153 | 28 | 0.7 | 205 | .... | 93 | 35 | 168 | 701 |
| 3 | .......... | Augusta, private well near northwest corner of city.[b] | ... | Archie J. Weith[a]. | ... | .... | .... | .... | .... | 0.0 | 399 | .... | 45 | .... | 844 |
| 4 | .......... | Augusta,[c] well one-half mile south of No. 3.[a] | ... | do. | ... | .... | .... | .... | .... | .0 | 495 | .... | 280 | .... | 1,487 |
| 5 | .......... | Augusta[d] one of Atchison, Topeka & Santa Fe Ry. wells. | ... | do. | ... | .... | .... | .... | .... | .... | 259 | 109 | 24 | .... | 518 |
| 6 | 1902. Sept. 25 | Douglass, well | ... | Atchison, Topeka & Santa Fe Ry.[a] | 16 | Tr. | 106 | 24 | 46 | 204 | .... | 46 | 54 | .... | ..... |
| 7 | Sept. 30 | Eldorado, well | ... | do. | 23 | Tr. | 129 | 16 | 25 | 209 | .... | 35 | 42 | .... | ..... |
| | | ASSAY. | | | | | | | | | | | | | |
| 1 | 1907. May 12 | Eldorado, city water, well, and laterals. | 30 | .................. | ... | .0 | .... | .... | .... | .0 | 410 | 53 | 44 | .... | ..... |

[a] Made at laboratories of the University of Kansas.
[b] In Whitewater River flats.
[c] In Whitewater River bottom.
[d] In Walnut River flats.

## CHASE COUNTY.

Chase County is underlain by Permian and Pennsylvanian rocks, both of which normally yield highly mineralized hard waters.

Analysis 3 (Table 9) shows a salt water, and analysis 2 a water of high temporary and low permanent hardness. Analyses 1, 5, and particularly 4 signify that the waters of which they are tests have marked permanent hardness. The waters assayed have high temporary and permanent hardness.

All of the tested well waters of Chase County are from the valley of Cottonwood River, and the analyses and assays should be compared with those waters at Durham, Marion, Florence, and Peabody in Marion County, with the analysis at Braddocks in Harvey County, and with the analysis at Emporia in Lyon County, which represent waters in the valleys of Cottonwood River and its tributaries. Such a comparison reveals the fact that the permanent hardness of all the shallow well waters and of some of the spring waters is decidedly high.

TABLE 9.—*Analyses and assays of underground waters of Chase County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1897. Apr. 8 | Clements, Atchison, Topeka & Santa Fe Ry. | .. | Atchison, Topeka & Santa Fe Ry. | 19 | .... | 122 | 20 | 15 | 174 | .... | 94 | .... | 23 | 56 | 526 |
| 2 | 1908. July | Cottonwood Falls, spring (new public supply).[a] | | Archie J. Weith. | 9.4 | 0.4 | 98 | 12 | 11 | 0.0 | 333 | 8.2 | 0.56 | 4 | .... | 287 |
| 3 | 1902. Sept. 30 | Elmdale, artesian well. | .. | Atchison, Topeka & Santa Fe Ry. | 54 | .7 | 17 | Tr. | 29 | 48 | .... | 7.7 | .... | 12 | .... | ... |
| 4 | Sept. 23 | Saffordville, surface well. | .. | ......do........ | 20 | Tr. | 98 | 29 | 28 | 56 | .... | 304 | .... | 12 | .... | ... |
| 5 | 1897. Apr. 7 | Strong City, Atchison, Topeka & Santa Fe Ry. well. | .. | ......do........ | 8.6 | .... | 128 | 18 | 5.5 | 198 | .... | 59 | .... | 6.4 | 20 | 443 |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | 1905. July 28 | Cottonwood Falls, dug well at courthouse. | .. | Edward Bartow. | .... | .0 | ... | .... | .... | .0 | 379 | 344 | .... | 124 | .... | ... |
| 2 | ...do..... | Cottonwood Falls, well 4 miles east of city. | 31 | ......do........ | .... | .0 | ... | .... | .... | .0 | 385 | 61 | .... | 24 | .... | ... |
| 3 | ...do..... | Elmdale, well... | 35 | ......do........ | .... | .0 | ... | .... | .... | .0 | 295 | 113 | .... | 438 | .... | ... |

[a] Made at laboratories of University of Kansas.

## CHAUTAUQUA COUNTY.

Chautauqua County is underlain by Pennsylvanian rocks, which may be expected to yield hard waters. Not much is known about the composition of the ground waters of the county, as only two of them were tested. Both the analysis and the assay (Table 10) show hard waters.

TABLE 10.—*Anatys s and assay of underground waters from Chautauqua County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1897. Apr. 7 | Chautauqua Springs, Chautauqua springs.[a] | .. | E. H. S. Bailey and E. C. Franklin. | 28 | 2.4 | 37 | 8.4 | 27 | 109 | .... | 49 | 34 |
| | | ASSAY. | | | | | | | | | | | |
| 1 | 1907. May 10 | Cedarvale, well of Fred Cox, on Main Street. | 38 | ........................ | ... | .0 | ... | ... | .... | .0 | 325 | (b) | 524 |

[a] Kansas Univ. Geol. Survey, vol. 7.

[b] $SO_4$ greater than 626.

## CHEROKEE COUNTY.

Pennsylvanian rocks underlie all of Cherokee County except the southeast corner, which is underlain by Mississippian rocks. There are two distinct sources of water supply in this county—the shallow wells, most of which yield hard waters, and the deep wells, whose waters come from the Ozark dome and are not uncommonly high in sodium and chlorides and usually smell of hydrogen sulphide.

The results of tests of underground waters in Cherokee County are recorded in Table 11. Analysis 1 represents a test of a deep well water at Columbus; assay 9 is a test of the same water and indicates higher sulphates than are indicated by the analysis. Analysis 3 shows the water of the deep well at Empire to be low in sulphates, differing in this respect from assay 12, which indicates high sulphates and low alkalinity. Assays 16, 21, and 27 are also tests of deep well waters, and all of them, except assay 16, indicate hard waters. Assays 1, 10, 14, 18, 19, 20, 22, 23, 24, 25, and 26 are tests of shallow well waters. Two of these, 19 and 20, indicate high temporary hardness, and all show marked permanent hardness. Marked permanent hardness is shown, too, by assays 2, 3, and 13, which are tests of waters from three wells somewhat deeper than the shallow ones. Assay 1 is a test of a soft water. Assays 4 to 7 are tests of the waters of the well-known springs at Baxter. Assays 11, 15, and 17 are also tests of spring waters, and these appear to be rather softer than those at Baxter.

TABLE 11.—*Analyses and assays of underground waters from Cherokee County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | .......... | Columbus, well [a] [b].... | 1,400 | G. H. Failyer and J. T. Willard. | 6.7 | 0.4 | 43 | 22 | (Na) 115 (K) 3.4 | .... | 14 | 36 | .... |
| 2 | 1901. June | Baxter Springs, spring No. 2. [a] | ..... | A. B. Knerr........ | 13 | 3.6 | 126 | 5.4 | (Na) 12 (K) 4 2 | 246 | 142 | 16 | .... |
| 3 | 1899. Dec. 27 | Empire, waterworks well. [c] | .... | Edward Bartow.. | 17 | 3.9 | 87 | 1.0 | .......... | .... | 24 | 5 | 282 |

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | | |
| 1 | 1905. July 10 | Baxter Springs, city well at River and Military Streets. | ..... | .................. | 0.0 | 0.0 | 261 | Tr. | 4.6 |
| 2 | ...do.... | Baxter Springs, well of Dr. C. M. Jones [d]. | 225 | .................. | .0 | .0 | 229 | 79 | 14 |
| 3 | ...do.... | Baxter Springs, well of St. Louis and San Francisco R. R. [e] | 285 | .................. | 2.5 | .0 | 256 | 383 | 6.6 |
| 4 | ...do.... | Baxter Springs, spring No. 1............ | ..... | .................. | 2.0 | .0 | 239 | 168 | 15 |
| 5 | ...do.... | Baxter Springs, spring No. 2 [f] .......... | ..... | .................. | .0 | .0 | 243 | 130 | 20 |
| 6 | ...do.... | Baxter Springs, spring of Mr. Newhouse on north side of Spring Creek. | ..... | .................. | .0 | .0 | 96 | 56 | 25 |
| 7 | ...do.... | Baxter Springs, "Doty Spring" on north side of Spring Creek. [g] | ..... | .................. | .5 | .0 | 213 | 119 | 15 |
| 8 | July 14 | Columbus, dug well of Hotel Middaugh.. | ..... | Edward Bartow.. | .0 | .0 | 134 | ([h]) | 91 |
| 9 | ...do.... | Columbus, well of waterworks........... | 1,400 | .....do.......... | .0 | .0 | 341 | 60 | 40 |
| 10 | ...do.... | Columbus, well 1 mile south and three-fourths mile east of city. [i] | 31 | .....do.......... | .0 | .0 | 36 | 88 | 178 |
| 11 | ...do.... | Columbus, spring one-half mile south and one-fourth mile west of city. [j] | ..... | .....do.......... | .0 | .0 | 71 | Tr. | 9.7 |
| 12 | ...do.... | Empire well of waterworks [k]............ | 1,004 | .....do.......... | .0 | .0 | 279 | 84 | 9.2 |
| 13 | July 13 | Empire well [l] ........................ | 125 | .....do.......... | Tr. | .0 | 80 | 119 | 22 |
| 14 | ...do.... | Empire well 2 miles north and 2 miles west of city. | 20 | .....do.......... | .0 | .0 | 162 | 113 | 65 |
| 15 | ...do.... | Empire, Chico Spring west of city....... | ..... | .....do.......... | .0 | .0 | 210 | 37 | 22 |
| 16 | July 12 | Galena [m]................................ | 968 | .....do.......... | .0 | .0 | 168 | Tr. | 6.6 |
| 17 | July 13 | Galena, Tillman Spring northeast of city. | ..... | .....do.......... | 0 | .0 | 133 | 42 | 12 |
| 18 | July 15 | Hallowell, city well.................... | 33 | .....do.......... | .0 | .0 | 187 | 328 | 32 |
| 19 | July 10 | Lowell, city well [n] ...................... | 30 | .....do.......... | .0 | .0 | 299 | 56 | 30 |
| 20 | ...do.... | Lowell, well of C. S. Yost................ | ..... | .................. | Tr. | .0 | 406 | 530 | 50 |
| 21 | ...do.... | Scammon, well of city waterworks....... | 816 | Edward Bartow.. | 1.8 | .0 | 117 | 86 | 25 |
| 22 | ...do.... | Scammon, well at Second Street and Sixth Avenue. | 22 | .....do.......... | 0 | .0 | 7.8 | 238 | 86 |
| 23 | ...do.... | Scammon, shallow well 2 miles north of city. | ..... | .....do.......... | Tr. | .0 | 116 | ([o]) | 20 |

[a] Kansas Univ. Geol. Survey, vol. 7.
[b] Lithium (Li), 1; manganese (Mn), 2; $S_2O_3$, 8.4.
[c] The well is 1,004 feet deep and 10 inches in diameter to 175 feet 6⅝ inches to 320 feet and 4 inches to the bottom.
[d] Drilled May, 1904. Is used by the Baxter Mineral Springs Water Co. to supply the city.
[e] Sample taken from tank.
[f] 125 feet southeast of spring No. 1.
[g] Situated at edge of Spring Creek in back yard.
[h] $SO_4$ greater than 626.
[i] Dug in 1869. Has never failed.
[j] Water peddled in city.
[k] No longer used as source of public supply.
[l] Originally a prospect hole.
[m] Used at the ice plant and sold in the city.
[n] At 20 feet a gravel stratum yields some water; this well is reputed the softest of the city.
[o] $SO_4$ greater than 626.

TABLE 11.—*Analyses and assays of underground waters from Cherokee County*—Cont'd.

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | | ASSAYS—continued. | | | | | | | |
| 24 | 1905. July 10 | Weir, well south of Main Street, one-half mile west of St. Louis and San Francisco R. R. tracks. [a] | ..... | Edward Barlow . | 0.0 | 0.0 | 185 | 530 | 50 |
| 25 | ...do.... | Weir, shallow well south of Main Street, one-half mile west of St. Louis and San Francisco R. R. [a] | ........ | ....do............ | Tr. | .0 | 16 | 202 | 66 |
| 26 | ...do.... | Weir, well 5 blocks west and 1 block south of Main Street and St. Louis and San Francisco R. R. tracks. | 18 | .....do............ | Tr. | .0 | 239 | 56 | 30 |
| 27 | ...do.... | Weir, well at ice plant [b] ................ | 525 | .....do............ | .0 | .0 | 462 | 35 | 35 |

[a] Water 3 feet from surface. [b] Used for public water supply.

## CHEYENNE COUNTY.[1]

Cheyenne County occupies a region of high plains traversed by Republican River, which has cut a valley about 200 feet below the general plain surface. The highlands are covered with Tertiary grit, which, as revealed in Republican and Arikaree valleys, is underlain by Pierre shale. The Niobrara chalk and limestone lie at a depth of 1,000 feet or more, but their precise position has not been ascertained. The thickness of this formation and the underlying Benton group is about 900 feet in northwest Kansas, and the depth to the Dakota sandstone is probably over 2,300 feet in Cheyenne County. Undoubtedly, this sandstone contains water under sufficient pressure to rise several hundred feet in a well but not enough to afford a flow, even in the deeper valleys. Apparently the beds lie nearly level or dip slightly to the west. So far as is known, there have been no borings in the county sufficiently deep to reach the chalk. On the high plains good water supplies for pump wells are usually obtained by sinking deeply into the "mortar beds," or Tertiary grit, and in the valleys the alluvial deposits usually yield considerable water. It is by no means uncommon in Cheyenne County to find valleys along the principal tributaries of the Republican River well watered the year round without any artificial application. The valleys have been eroded to the base of the Tertiary, and an outlet to the general body of underground water has thus been provided, so that constant seepage is in progress, forming pools of living water here and there along the streams, and in places saturating the soil of the valleys to so great an extent that even in dry seasons further application of water is not desirable.

[1] Abstracted in large part from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 292, and from Report of the Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 99.

Cheyenne County is interesting to the student of the water problem on account of the general diversity of conditions existing. In the central part of the county, and again to the northwest and north, certain areas of Cretaceous rocks are exposed. Even in the very center of the county, at St. Francis, is a small shale area sufficient to interfere materially with the production of water. In few counties in the State have more wells been drilled than in this, and in few localities have the people been more determined to obtain water from the Cretaceous shales than here, but almost every attempt has failed. Success following such efforts has probably been due to fissures in the shale leading off from the Tertiary water. The evidence given by the wells also seems to indicate that the surface of the Cretaceous floor is more irregular here than in most localities. Two wells are reported only a few yards apart, one of which is wholly in the Cretaceous deposits, while the other is wholly in the Tertiary.

The only available analysis (Table 12) is of a soft water from a well in St. Francis. The assays (Table 12) are tests of shallow well waters in the Republican River valley and indicate soft waters.

TABLE 12.—*Analysis and assays of well waters from Cheyenne County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | |
| 1 | 1909. | St. Francis, well | 30 | Chicago, Burlington & Quincy R. R. | [a]76 | 75 | 26 | 72 | 216 | .... | 54 | 24 |
| | | ASSAYS. | | | | | | | | | | |
| 1 | 1907. Oct. 4 | St. Francis, well at court-house. | 10 | | .0 | ... | ... | .... | .0 | 211 | Tr. | 15 |
| 2 | ...do... | St. Francis, well at Commercial Hotel. | 20 | | .0 | ... | ... | .... | .0 | 271 | Tr. | 26 |
| 3 | ...do... | St. Francis, well of Chicago, Burlington & Quincy R. R. | 30 | | .0 | ... | ... | .... | .0 | 280 | Tr. | 20 |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.

## CLARK COUNTY.

Clark County extends from the high plains on the divide south of Arkansas River into Cimarron Valley. The plains are capped by Tertiary deposits underlain to the north by Dakota sandstone and to the south by lower Cretaceous sandstones and shales. To the south the underlying "Red Beds" are exposed over a wide area. To the north water for pump wells is obtained from the basal portion of the Tertiary deposits and from the underlying sandstones. In the "Red Beds" area the alluvial deposits in the valleys are the only sources of supply. Some years ago an attempt was made near Lexington to obtain water in the "Red Beds" by boring 300 feet deep, but only salt water was obtained. No artesian fresh waters are to be expected in this county from the "Red Beds," and as this formation is probably very thick, the outlook is discouraging.[a]

The two analyses (Table 13) represent very different types of water. Analysis 1 is a test of water from the Permian deposits; analysis 2 shows the quality of water from the Tertiary. The former is hard, for it is high in calcium and sulphates; the latter is soft and satisfactory. The assays in Table 13 represent tests of waters from the Permian rocks. These waters are highly mineralized and all except the two, of which assays 5 and 9 are tests, have great permanent hardness. Assays 6 and 7 show waters very high in chlorides.

TABLE 13.—*Analyses and assays of underground waters from Clark County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | 1902. Oct. 25 | Englewood, surface well. | ... | Atchison, Topeka & Santa Fe Ry. | 60 | Tr. | 114 | 42 | 43 | 196 | 155 | 45 | .... |
| 2 | 1908. Sept. | Minneola, well | 125 | Chicago, Rock Island & Pacific Ry. | ... | [b]8.9 | 60 | 15 | 16 | 117 | 25 | 16 | 258 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1908. Jan. 2 | Ashland, well at schoolhouse | ...... | Tr. | 0.0 | 222 | 344 | 26 |
| 2 | ...do..... | Ashland, public well[c] | 60 | .0 | .0 | 245 | 430 | 359 |
| 3 | ...do..... | Ashland, well of Frank Abel[d] | 40 | .0 | .0 | 258 | 492 | 41 |
| 4 | ...do..... | Ashland, well of F. P. Kerns | 35 | .0 | .0 | 197 | 492 | 26 |
| 5 | 1907. Dec. 31 | Englewood, well of Englewood Light & Water Co. at edge of Five Mile Creek north of block 51 | 60 | .0 | .0 | 326 | 70 | 36 |
| 6 | ...do..... | Englewood, well at Third Street and Claremont Avenue | ...... | .0 | .0 | 430 | ([e]) | 1,017 |
| 7 | ...do..... | Englewood, well at Price restaurant, Fourth Street, block 32 | ...... | .0 | .0 | 445 | ...... | 1,198 |
| 8 | ...do..... | Englewood, well of Alva Milling & Elevator Co., north of block 51 | 14 | .0 | .0 | 317 | 286 | 226 |
| 9 | ...do..... | Englewood, public well on Third Street, a little northeast of the well of Englewood Light & Water Co | ...... | .0 | .0 | 300 | 36 | 36 |

[a] Description abstracted from Prof. Paper U. S. Geol. Survey No. 32, p. 292.
[b] $SiO_2+Fe_2O_3+Al_2O_3$.
[c] 35 feet to water.
[d] 25 feet to water.
[e] $SO_4$ greater than 626.

## CLAY COUNTY.

Clay County is immediately underlain by Permian rocks, except in the western and northern parts, which are underlain by the Dakota sandstone.

Analysis 1, Table 14, shows that the city water at Clay Center, which is derived from wells in the fluviatile deposits of Republican River, is very hard. Analysis 2 represents a test of water in a shallow well and indicates low permanent and high temporary hardness. The assays were made on the same waters that were tested by the two analyses and confirm the results.

TABLE 14.—*Analyses and assays of underground waters from Clay County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1908. Sept. | Clay Center, city waterworks, 5 wells. | 26–38 | Chicago, Rock Island & Pacific Ry. | .. | a 22 | 186 | 41 | 28 | 193 | .... | 321 | 27 | ... | 818 |
| 2 | ...do..... | Clifton, city waterworks, wells. | 60 | Missouri Pacific Ry. | 32 | 1.3 | 62 | 25 | 35 | 169 | .... | 29 | 15 | 9.2 | 378 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Feb. 26 | Clay Center, public water supply from 5 wells. | 26–38 | .................. | .. | .0 | ... | .. | .... | .0 | 358 | 328 | 24 | ... | .... |
| 2 | Feb. 25 | Clifton, public water supply, well. | b 60 | .................. | .. | Tr. | ... | .. | .... | .0 | 263 | Tr. | 14 | ... | .... |
| 3 | Aug. 5 | .....do................ | b 60 | .................. | .. | .0 | ... | .. | .... | .0 | 253 | Tr. | 20 | ... | .... |

a $SiO_2+Fe_2O_3+Al_2O_3$.

b Water stratum at 53 feet.

## CLOUD COUNTY.

In Cloud County the divide between Solomon and Republican rivers is capped by Benton shale and the lower lands are excavated in Dakota sandstone. This sandstone yields water to many shallow wells, both in the area of its outcrop and on the divide, in borings which pass through 25 to 150 feet of Benton shale. The conditions are unfavorable for artesian waters. The Dakota sandstone is underlain by shale, sandstone, and limestone of the Permian series, which are probably several hundred feet thick, and although these rocks as a rule contain water under considerable pressure, it is ordinarily too salty for domestic use.[1]

[1] Description abstracted from Prof. Paper U. S. Geol. Survey No. 32, p. 292.

TABLE 15.—*Analyses and assays of underground waters from Cloud County.*

[Parts per million.]

| No | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1902. Dec. 8 | Clyde, Chicago, Rock Island & Pacific Ry. | ........ | Kennicott Water Softener Co. | 25 | 1.8 | 92 | 9 | 42 | 161 | ........ | 45 | 31 | ........ | ........ |
| 2 | 1908. Sept. | Clyde, city waterworks, well. | 100 | Chicago, Rock Island & Pacific Ry. | ........ | *a* 11 | 89 | 25 | 121 | 160 | ........ | 57 | 186 | ........ | 649 |
| 3 | 1909. ........ | Concordia, well | 30 | Chicago, Burlington & Quincy R. R. | ........ | *a* 62 | 334 | 33 | 100 | 474 | ........ | 174 | 154 | ........ | ........ |
| 4 | 1902. Sept. 17 | ....do | ........ | Atchison, Topeka & Santa Fe Ry. | 19 | Trace. | 96 | 8.3 | 47 | 179 | ........ | 44 | 24 | ........ | ........ |
| 5 | ........ | Concordia, 5 wells | 45–46 | Missouri Pacific Ry | 57 | .2 | 201 | 31 | 73 | 255 | ........ | 199 | 113 | 126 | 1,056 |
| 6 | ........ | Jamestown, well | 58 | ....do | 20 | 1.8 | 104 | 10 | 17 | 182 | ........ | 12 | 17 | 6.5 | 371 |
| 7 | Sept. 19 | Miltonvale, well | ........ | Atchison, Topeka & Santa Fe Ry. | 33 | 5.1 | 68 | 9.1 | 27 | 117 | ........ | 62 | 6 | ........ | ........ |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Feb. 2 | Clyde, city waterworks well. | 100 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 344 | 36 | 30 | ........ | ........ |
| 2 | Feb. 25 | Concordia, city waterworks, 35 wells. | 43 | ........ | ........ | ...do.. | ........ | ........ | ........ | .0 | 402 | 36 | 55 | ........ | ........ |
| 3 | Aug. 3 | Concordia, Concordia Ice and Cold Storage Co. well. *b* | 48 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 394 | 112 | 50 | ........ | ........ |

*a* $SiO_2+Fe_2O_3+Al_2O_3$.

*b* Put down in 1902; used to supply the natatorium.

In Table 15, analyses 1 to 5 record tests of wells in Republican River valley. Of these five, 2, 3, and 5 show high chlorides, and all of them, especially Nos. 2 and 5, indicate hard waters. Analysis 6 shows a very satisfactory water from a well in the valley of Buffalo Creek. The results shown in analysis 7 indicate a rather hard water. Assays 1 and 2 show waters of marked temporary hardness. Assay 3 shows a water of marked permanent hardness.

## COFFEY COUNTY.

Coffey County is underlain by Pennsylvanian rocks, which may be expected to yield hard waters. All of the assays in Table 16, except Nos. 6 and 7, show waters of high temporary and permanent hardness; assays 2 and 4 indicate high chlorides.

TABLE 16.—*Assays of underground waters from Coffey County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1905. July 26 | Burlington, well at courthouse | 26 | Edward Bartow | 0.0 | 0.0 | 436 | 238 | 49 |
| 2 | ...do.... | Burlington, well in northeastern part of city. | 22 | .....do | .0 | .0 | 542 | 85 | 238 |
| 3 | ...do.... | Burlington, Kingsbury, well in southern limits of city. | 16 | .....do | .0 | .0 | 480 | 55 | 71 |
| 4 | July 25 | Burlington, shallow well 1¾ miles south and 2½ miles east of bridge. | .... | .....do | .0 | .0 | 281 | 80 | 149 |
| 5 | ...do.... | Leroy, public well | 25 | .....do | .0 | .0 | 442 | 67 | 46 |
| 6 | ...do.... | Leroy, well 4½ miles north and 1 mile west of city. | 15 | .....do | .0 | .0 | 267 | Tr. | 26 |
| 7 | ...do.... | Leroy, drilled well 2 miles east of city | 25 | .....do | .0 | .0 | 130 | .... | 24 |
| 8 | 1907. Aug. 27 | Waverly, well[a] | 25 | | .0 | .0 | 301 | 130 | 19 |

[a] Blasted out of limestone rock. Public supply.

## COMANCHE COUNTY.

The geologic conditions in Comanche County are similar to those in Clark County to the west.

Analyses 1 and 2, Table 17, represent tests of waters from the Permian, and analysis 3 is a test of one from the Tertiary deposits. Of these three the last shows a somewhat softer water than the other two, which denote waters of high permanent and temporary hardness. The assays show the quality of the waters of several shallow wells that are located in the valley of Cavalry Creek between Protection and Coldwater. These waters are all soft, except that of which assay 2 is a test.

TABLE 17.—*Analyses and assays of underground waters from Comanche County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| | 1901. | | | | | | | | | | | | | |
| 1 | May 24 | Protection, well | .. | Atchison, Topeka & Santa Fe Ry. | .. | .... | 90 | 24 | 38 | 129 | .... | 147 | 27 | 39 |
| | 1902. | | | | | | | | | | | | | |
| 2 | Oct. 21 | Protection, surface well | .. | ......do | 29 | 2.2 | 55 | 20 | 68 | 175 | .... | 45 | 18 | .... |
| 3 | Oct. 14 | Wilmore, surface well | .. | ......do | 20 | Tr. | 86 | 7.6 | 16 | 127 | .... | 39 | 21 | .... |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1908. | | | | | | | |
| 1 | Jan. 3 | Protection, well of J. A. Wuchter | 22 | 0.0 | 0.0 | 237 | Tr. | 16 |
| 2 | ...do.... | Protection, well of P. P. Wuchter | 22 | .0 | .0 | 134 | 530 | 30 |
| 3 | ...do.... | Protection, well of B. U. Towner's livery barn | 42 | .0 | .0 | 226 | 45 | 20 |
| 4 | ...do.... | NW. ¼ sec. 24, T. 32 S., R. 19 W., well at house of Overstreet Ranch. | .... | Tr. | .0 | 267 | Tr. | 20 |
| 5 | ...do.... | NE. ¼ sec. 1, T. 33 S., R. 19 W., well of Mr. Fish | 64 | .0 | .0 | 262 | Tr. | 15 |
| 6 | ...do.. | Coldwater, well of Jeff. Price, block 32, lot 1 | 85 | .0 | .0 | 158 | Tr. | 10 |
| 7 | ...do.... | Coldwater, public well[a] | 65 | Tr. | .0 | 178 | Tr. | 30 |
| 8 | ...do.... | Coldwater, well at rear of courthouse | 78 | .0 | .0 | 133 | Tr. | 10 |

[a] Iron, possibly from galvanized iron extension at bottom of well.

## COWLEY COUNTY.

Most of Cowley County is underlain by Permian rocks, but the valley of Grouse Creek and the eastern part of the county is underlain by the Pennsylvanian series. Both rock series yield hard waters.

Analysis 1, Table 18, shows a water high in calcium, sodium, sulphates, and chlorides. Analyses 2 and 3 show waters of very high permanent and considerable temporary hardness. Analysis 4 is a test of a water very high in calcium, sodium, sulphates, and chlorides. The permanent hardness disclosed by analysis 5 is less than that of the other well waters, but the temporary hardness of the water is very high. Of the assays recorded in Table 18, No. 5 is the only one which does not indicate very great permanent hardness.

TABLE 18.—*Analyses and assays of underground waters from Cowley County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1902. Sept. 30 | Arkansas City, surface well | ........ | Atchison, Topeka & Santa Fe Ry. | 24 | Trace. | 106 | 23 | 85 | 110 | ........ | 163 | ........ | 133 | ........ | ........ |
| 2 | 1903. Mar. 2 | Arkansas City, well at roundhouse. | ........ | ....do | 17 | ........ | 177 | 21 | 142 | 137 | ........ | 258 | ........ | 241 | 144 | 1.137 |
| 3 | ........ | Arkansas City, city water | ........ | Missouri Pacific Ry. | 25 | 16 | 74 | 75 | 104 | 172 | ........ | 198 | ........ | 159 | 127 | 957 |
| 4 | ........ | Arkansas City, well | 25 | St. Louis & San Francisco R. R. | 17 | 3.4 | 807 | 182 | 2,260 | 125 | ........ | 802 | ........ | 4.696 | ........ | ........ |
| 5 | 1907. ........ | Winfield, city wells | ........ | F. W. Bushong | 34 | 1.5 | 108 | 26 | 19 | 0.0 | 378 | 29 | 6 | 17 | ........ | 374 |
| 6 | ........ | Winfield, well in Walnut River Bottom, 6 miles above Winfield.*a* | ........ | ....do | 22 | 1.5 | 168 | 38 | 44 | .0 | 705 | 21 | 12 | 31 | ........ | 629 |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | 1907. Jan. 12 | Arkansas City, "the spring" city supply. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 263 | 79 | ........ | 100 | ........ | ........ |
| 2 | ...do | Arkansas City, "the well" city supply. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 241 | 121 | ........ | 116 | ........ | ........ |
| 3 | ...do | Arkansas City, well of the Polar Ice Co. | ........ | ........ | ........ | .5 | ........ | ........ | ........ | .0 | 273 | 287 | ........ | 348 | ........ | ........ |
| 4 | ...do | Arkansas City, well of Arkansas City Ice & Cold Storage Co. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 313 | 530 | ........ | 271 | ........ | ........ |
| 5 | Jan. 17 | Winfield, new well of the city of Winfield. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 313 | Trace. | ........ | 30 | ........ | ........ |
| 6 | ...do | Winfield, well of Seymour Packing Co. | 30 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 324 | 626 | ........ | 136 | ........ | ........ |

*a* Made at laboratories of University of Kansas.

## CRAWFORD COUNTY.

Crawford County is underlain by Pennsylvanian rocks, which may be expected to yield hard waters, but in the southeastern part of the county are deep wells that derive their waters from the Ozark dome.

Analyses 2, 4, 6, and 7, Table 19, together with assays 2, 3, 4, 5, 7, 10, 14, and 15 of the same table are tests of waters that come from wells about 900 feet deep and are believed to be derived from the Ozark dome. These waters differ considerably in character, but most of them are sulphureted and all have marked permanent hardness. The greater part of these deep-seated waters have considerable temporary hardness and some of them are rather high in chlorides. Analysis 6 and assay 13 are tests of water from a well 1,500 feet deep, which is believed by the owners to be derived from the St. Peter sandstone. Analysis 5 is a test of a spring water which is shown to be uncommonly soft for a ground water from the State of Kansas. Analysis 1 and also assays 1, 6, 8, 9, 11, and 12 are tests of shallow-well waters. These waters are very hard and some of them are high in chlorides.

TABLE 19.—*Analyses and assays of underground waters from Crawford County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | | Arcadia, well | | St. Louis & San Francisco R. R. | 2.2 | 3.2 | 59 | 26 | 186 | 148 | | 46 | 257 | | |
| 2 | | Cherokee, well, city supply [a] [b] | 916 | E. H. S. Bailey and E. S. Hull. | 8.9 | | 62 | 31 | (Na) 131; (K) 8.5 | 338 | | 142 | 94 | | |
| 3 | 1909. | Cherokee | | C. C. Young | 8.2 | 10 | 62 | 29 | 89 | 321 | | 99 | 85 | | |
| 4 | | Frontenac, new artesian well | | Atchison, Topeka & Santa Fe Ry. | | | 43 | 26 | 520 | 562 | | 118 | 203 | 72 | 1,544 |
| 5 | | Galena, Cave Spring [a] | | E. H. S. Bailey and E. McCullom. | 18 | 2.8 | 20 | 1.6 | 2.5 | 33 | | 34 | | | |
| 6 | 1898. Nov. 10 | Girard, artesian well, city supply | 960 | Atchison, Topeka & Santa Fe Ry. | | | 92 | 58 | 244 | 187 | | 112 | 408 | 89 | 1,188 |
| 7 | 1905. June 6 | Pittsburg, well of Pittsburg Water Supply Co. [c] [d] | 1,500 | Dearborn Chemical Co. | 1.7 | 1.1 | 50 | 27 | 66 | 132 | | 79 | 55 | | |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1905. June 27 | Arcadia, well west side of Nelson Street. | | Edward Bartow | | .0 | | | | .0 | 17 | 82 | 64 | | |
| 2 | ...do... | Arcadia, well at brickyard [e] | 1,002 | ...do... | | Trace. | | | | .0 | 304 | 37 | 269 | | |
| 3 | July 10 | Cherokee, well at waterworks | [f] 913 | ...do... | | 6.5 | | | | .0 | 434 | 238 | 81 | | |
| 4 | ...do... | Cherokee, well at Weir Junction Coal Co. No. 2. | 904 | ...do... | | 1.0 | | | | .0 | 371 | 60 | 86 | | |
| 5 | ...do... | Cherokee, well at No. 10 shaft of Fleming Coal Co. | [g] 965 | ...do... | | Trace. | | | | .0 | 434 | Trace. | 122 | | |
| 6 | July 6 | Frontenac, well 1 mile west of city [h] | 18 | | | Trace. | | | | .0 | 699 | | 448 | | |
| 7 | ...do... | Frontenac, well of Mount Carmel Coal Co. | 901 | | | .0 | | | | .0 | 411 | Trace. | 104 | | |
| 8 | July 3 | Girard, well in front of Gaylord's drug store. | 32 | | | 1.0 | | | | .0 | 444 | 344 | 413 | | |
| 9 | ...do... | Girard, well on Ozark street two houses north of Huber House. | 40 | | | Trace. | | | | .0 | 494 | 460 | 318 | | |
| 10 | ...do... | Girard, storage and aerating reservoir, city waterworks. [d] | 960 | | | Trace. | | | | .0 | 303 | 154 | 413 | | |
| 11 | ...do... | Girard, Raymond Spring, 1 mile east of city. | | | | 2.5 | | | | .0 | 168 | 168 | 9.5 | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | July 5 | Pittsburg, well of J. S. Hite, 2 miles west and 1 mile south of city. | 16 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 628 | 530 | 94 | ........ | ........ |
| 13 | July 6 | Pittsburg, well of Pittsburg Water Supply Co. *d* | 1,500 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 308 | 60 | 85 | ........ | ........ |
| 14 | ...do..... | Pittsburg, well of Hull and Dillon. | 1,050 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 288 | 222 | 1,892 | ........ | ........ |
| 15 | ...do..... | Pittsburg, well of Cockrell Zinc Co., west of city. | 910 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 467 | 113 | 110 | ........ | ........ |

*a* Kansas Univ. Geol. Survey, vol. 7.
*b* Al, 1.9.
*c* Analysis furnished by Dow R. Gwinn.
*d* Odor of $H_2S$.
*e* Water at 900 feet.
*f* Water rises within 100 feet of surface.
*g* Water rises within 65 feet of surface. Slight odor of $H_2S$.
*h* Wells in city are very few and poor. $SO_4$ greater than 626.

## DECATUR COUNTY.[1]

Decatur County is an undulating region of high plains cut to a depth of 200 to 300 feet by the valleys of Beaver, Sappa, and Prairie Dog creeks. The entire area appears to be mantled by the Tertiary "mortar beds" and other deposits, although possibly these have been cut through in the deeper portions of some of the valleys.

The county is underlain by Pierre shale, which is thin to the east but thickens rapidly to the west. The underlying Niobrara chalk and the Benton group have a thickness of about 900 feet, and dip gently to the west. These statements indicate that the Dakota sandstone probably lies at a depth of about 1,000 feet in the eastern portion of the county and considerably deeper on the higher lands in the west. Three deep wells have been bored in the county, at Jennings, Kanona, and Oberlin, which throw considerable light on the underground geology.

The boring at Jennings was sunk to a depth of 1,050 feet, and a large volume of water, rising to within about 400 feet of the surface, was found in the lower sandstone, which is probably the Dakota. At Kanona, in 1903, a deep boring had progressed to the depth of 1,620 feet. A sand (Dakota) was encountered at from 1,450 to 1,550 feet, which yielded water in considerable amount that rose to within about 450 feet of the surface. These borings prove that the Dakota sandstone extends westward in Kansas and contains a water supply, but, unfortunately, the head is too low to afford prospects for flowing wells, even on the lowest lands.

At Oberlin a well said to have a depth of about 1,000 feet, through chalk and shale to a bed of sandstone, yields a small flow of water (and gas). It is believed that this well is not deep enough to penetrate the Dakota sandstone and that it obtains its supply from the saliferous shales at the base of the Benton, a water horizon not reported in the boring at Kanona.

Analysis 1, Table 20, shows a soft water; analysis 2 one of high temporary hardness, and analysis 3 one of high permanent and temporary hardness. Assay 1 shows a water of high temporary and permanent hardness. Assays 2 and 3 indicate soft waters and assays 4 and 5 waters of high temporary hardness. Assay 6 is a test of the water of a flowing salt well. The chlorides are very high, the bicarbonates moderate in amount, and there are no sulphates, which is unusual in the deep-seated saline waters of Kansas.

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[1] Description abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 293–294.

TABLE 20.—*Analyses and assays of underground waters from Decatur County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | 1908. Sept. | Jennings, well | 36 | Chicago, Rock Island & Pacific Ry. | [a]18 | 72 | 18 | 8.5 | 142 | .... | 23 | 10 | 291 |
| 2 | 1909. ........ | Norcatur, well | 245 | Chicago, Burlington & Quincy R. R. | [a]82 | 82 | 25 | 22 | 196 | .... | 8.3 | 14 | .... |
| 3 | ........ | Oberlin, well | 16 | .....do | [a]41 | 140 | 39 | 86 | 337 | .... | 78 | 38 | .... |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1907. Oct. 2 | Cedar Bluffs, well at Chicago, Burlington & Quincy R. R. station. | 38 | 0.0 | 0.0 | 377 | 53 | 36 |
| 2 | Sept. 30 | Jennings, well of B. W. Simpson [b] | 40 | .0 | .0 | 290 | Trace. | 26 |
| 3 | ...do..... | Kanona, well of H. A. Hansen, sec. 17, T. 3 S., R. 27 W. | ........ | .0 | .0 | 236 | ...do... | 15 |
| 4 | Oct. 1 | Oberlin, city waterworks well | 38 | .0 | .0 | 317 | ...do... | 20 |
| 5 | ...do..... | Oberlin, well of Chicago, Burlington & Quincy R. R. | ........ | 1.0 | .0 | 394 | ...do... | 26 |
| 6 | ...do..... | Oberlin, flowing salt well [c] | [d]1,000 | .0 | .0 | 249 | .0 | 5,454 |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.
[b] Sunk in 1902.
[c] Natural gas bubbles up through the water.
[d] About.

## DICKINSON COUNTY.

Dickinson County is almost wholly underlain by Permian rocks, although in the northwest and southwest are patches of Dakota sandstone.

The city of Abilene gets its water from the Dakota sandstone and the supply is very satisfactory, as analyses 1 and 2 and assay 1 (Table 21) show. All of the other analyses recorded in this table show very hard waters. The permanent hardness is due to the large amount of calcium sulphate or gypsum that is dissolved by the waters from the Permian rocks. Erasmus Haworth (by letter) says that in some places in southern Dickinson County the gypsum is exposed immediately at the surface with hardly enough soil covering to hold rain water an hour after the rain.

In Table 21, analyses 5 and 12 show waters remarkably high in sulphates. All of the assays except No. 1 indicate highly mineralized waters high in sulphates.

TABLE 21.—*Analyses and assays of underground waters from Dickinson County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1902. Sept. 18 | Abilene, city water from sand springs. | ........ | Kennicott Water Softener Co. | 24 | 0.7 | 69 | 8.9 | 22 | 122 | ........ | 34 | ........ | 12 | ........ | ........ |
| 2 | 1908. Mar. 5 | ....do.... | ........ | Union Pacific R. R. | 18 | 4.7 | 41 | 14 | 25 | 87 | ........ | 41 | ........ | 20 | ........ | 253 |
| 3 | ...do.... | Chapman, well.... | 67 | ....do.... | 23 | 1.5 | 87 | 1.1 | 66 | 111 | ........ | 136 | ........ | 28 | ........ | 453 |
| 4 | 1904. Feb. 26 | Enterprise, city waterworks well. | 42 | Atchison, Topeka & Santa Fe Ry. | 26 | ........ | 247 | 88 | 96 | 242 | ........ | 534 | ........ | 162 | 264 | 1,658 |
| 5 | ........ | Herington, flowing well for new city supply. | ........ | Kennicott Water Softener Co. | 24 | 8.4 | 563 | 148 | 130 | 341 | ........ | 1,631 | ........ | 224 | ........ | ........ |
| 6 | 1907. Sept. | Herington, reservoir fed by springs. | ........ | Chicago, Rock Island & Pacific Ry. | ........ | *a* 6.5 | 74 | 42 | 12 | 179 | ........ | 65 | ........ | 13 | ........ | 392 |
| 7 | Aug. 9 | Herington, McClave well [b] on sec. 12, T. 16 S., R. 4 E. | 60 | F. W. Bushong.... | 13 | 8 | 120 | 22 | 38 | 0 | 445 | 199 | 3 | 20 | ........ | 654 |
| 8 | ...do.... | Herington, Murray well [b] on sec. 12, T. 16 S., R. 4 E. | 90 | ....do.... | 14 | 9 | 83 | 56 | 35 | 0 | 465 | 47 | 6.3 | 11 | ........ | 433 |
| 9 | Aug. 28 | Herington, B. L. Thompson's well.[b] sec. 12, T. 16 S., R. 4 E. | 48 | ....do.... | 15 | 10 | 88 | 90 | 52 | .0 | 527 | 50 | 16 | 19 | ........ | 520 |
| 10 | Aug. 20 | Herington, well of D. Hauer[b] on sec. 12, T. 16 S., R. 4 E. | 50 | ....do.... | 14 | 10 | 75 | 65 | 30 | 0 | 500 | 34 | 5.5 | 9 | ........ | 431 |
| 11 | ...do.... | Herington, Dolan west well [b] on sec. 14, T. 16 S., R. 4 E. | 60 | ....do.... | 14 | 10 | 211 | 77 | 42 | 0 | 420 | 483 | 3.2 | 23 | ........ | 1,077 |
| 12 | ...do.... | Herington, Dolan east well [b] on sec. 18, T. 16 S., R. 5 E. | 60 | ....do.... | 15 | 12 | 592 | 112 | 69 | 0 | 362 | 1,555 | .3 | 48 | ........ | 2,739 |
| 13 | ........ | Solomon, well.... | 42 | Union Pacific R. R. | 21 | 1.2 | 106 | 12 | 111 | 130 | ........ | 248 | ........ | 55 | ........ | 685 |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | Aug. 2 | Abilene, city water—sand springs 4 miles west of city. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 156 | Trace. | ........ | 14 | ........ | ........ |
| 2 | Aug. 1 | Chapman, well at Union Pacific R. R. depot.[c] | ........ | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 447 | 103 | ........ | 45 | ........ | ........ |
| 3 | ...do.... | Chapman, well 2,000 feet west of Union Pacific R. R. depot.[d] | 65 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 273 | 136 | ........ | 30 | ........ | ........ |
| 4 | Aug. 2 | Enterprise, well, city water.. | 45 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 475 | 460 | ........ | 156 | ........ | ........ |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Aug. 12 | Herington, Prospect well No. 3 (east well).[e] | 104 | | | 14 | | | | .0 | 323 | | | 59 | | |
| 6 | ...do.... | Herington, West Prospect well.[f] | 130 | | | 18 | | | | .0 | 311 | | | 114 | | |
| 7 | Aug. 13 | Herington, Herington Ice & Cold Storage Co.'s two wells.[g] | 100 | | | 1.5 | | | | .0 | 312 | | | 199 | | |
| 8 | ...do.... | Herington, Thompson's well on D Street. | 52 | | | .0 | | | | .0 | 453 | 50 | | 19 | | |
| 9 | ...do.... | Herington, spring at edge of Lime Creek near city waterworks. | | | | .0 | | | | .0 | 408 | 168 | | 29 | | |
| 10 | Sept. 1 | Solomon, well of G. L. Cryderman. | 35 | | | .0 | | | | .0 | 317 | 208 | | 79 | | |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.
[b] Made at laboratories of the University of Kansas.
[c] For drinking.
[d] For engines.
[e] $SO_4$ greater than 626. Well is cased to 60 feet. Water is met at 97 feet. A flowing well put down in June, 1907. Iron may be derived from casing.
[f] $SO_4$ greater than 626. Well not cased and is 200 feet west of well No. 3. Put down in June, 1907.
[g] $SO_4$ greater than 626.

## DONIPHAN COUNTY.

Doniphan County is underlain by Pennsylvanian rocks which may be expected to yield hard waters. The glacial deposits that cover much of the county possibly afford a somewhat softer water.

Both the analysis and assays in Table 22 represent tests of the waters of wells sunk in the drift, and these waters have rather high temporary hardness but almost no permanent hardness.

TABLE 22.—*Analysis and assays of underground water from Doniphan County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1908. Sept. | Bendena, dug well of Chicago, Rock Island & Pacific Ry. | 75 | Chicago, Rock Island & Pacific Ry. | [a] 9.9 | 54 | 21 | 6 | 115 | ... | 28 | 0.9 | 244 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. July 17 | Troy, well of Wm. Stuart.[b] | 70 | ........ | .0 | ... | ... | .... | .0 | 334 | .0 | 40 | .... |
| 2 | ...do..... | Troy, well at Hotel Avon. | 70 | ........ | Tr. | ... | ... | .... | .0 | 432 | .0 | 45 | .... |

[a] $SiO_2+Fe_2O_3+Al_2O_3$. [b] Sunk in 1901.

## DOUGLAS COUNTY.

As Douglas County is underlain by Pennsylvanian rocks, hard waters may be expected except possibly from wells in glacial deposits.

All of the analyses recorded in Table 23 are tests of the waters of wells in Lawrence at the edge of Kansas River. The water from the wells of the Lawrence Water Co. has high temporary and considerable permanent hardness. Moreover, the water carries much iron in solution that has to be removed by aeration and the addition of chemicals before the water can be delivered to the public. The water of the wells of the Lawrence Paper Manufacturing Co. has greater permanent hardness than that of the water company. Analysis 5 shows the character of water from an old test hole.[1]

Assay No. 1 shows a soft water. The other assays indicate waters of marked permanent and temporary hardness.

[1] Kansas Univ. Geol. Survey, vol. 7, p. 151.

TABLE 23.—*Analyses and assays of underground waters from Douglas County.*

[Parts per million.]

| No. | Date. | Source. | Depth. | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$) | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1902. Nov. 15 | Lawrence, city well. | | Atchison, Topeka & Santa Fe Ry. | 33 | 2.3 | 116 | 21 | 57 | 227 | | 29 | | 67 | | |
| 2 | | Lawrence, 1 well of Lawrence Paper Manufacturing Co.[a] | | Dearborn Drug & Chemical Co. | 27 | 1.9 | 239 | 30 | 133 | 272 | | 226 | 42 | 204 | | 1,179 |
| 3 | 1907. June 4 | Lawrence, combined wells of Lawrence Paper Manufacturing Co.[a] | | Scaife | 21 | Tr. | 370 | 52 | 171 | 307 | | 321 | 70 | 288 | 26 | |
| 4 | Dec. 30 | Lawrence Water Co.'s wells[b] | | F. W. Bushong | 36 | .12 | 110 | 19 | 67 | .0 | 390 | 42 | .6 | 66 | | [c] 483 |
| 5 | | Lawrence, flowing salt well[d] | 1,400 | E. Bartow and H. M. Thompson. | 85 | 48 | 2,792 | 6,310 | 4,216 | | | | | [e] 30,066 | | |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | 1907. Mar. 1 | Baldwin, well of Baldwin Steam Laundry. | 42 | | | Tr. | | | | .0 | 117 | Trace. | | 20 | | |
| 2 | 1905. June 3 | Lakeview, well at club house | 18–20 | E. Bartow | | .0 | | | | .0 | 460 | 154 | | 50 | | |
| 3 | do | Lakeview, well on high ground | | do | | .0 | | | | .0 | 247 | 74 | | 20 | | |
| 4 | 1907. Aug. 30 | Lawrence, well at 231 Lincoln Avenue and North Lawrence Street. | | | | .0 | | | | .0 | 408 | 115 | | 59 | | |

[a] Analysis furnished by Irving Hill.
[b] Made at laboratories of University of Kansas.
[c] No turbidity before exposure to air. The 20 parts of suspended matter consist chiefly of $Fe_2O_3$ which separated from the water prior to analysis. Iron reported in the analysis is that which remained in solution.
[d] Kansas University Geological Survey, vol. 7, p. 51.
[e] Bromine, trace.

## EDWARDS COUNTY.[1]

Edwards County lies in Arkansas Valley and is mainly underlain by Dakota sandstone. On the bottom lands the sandstone is largely covered by alluvium; the highlands are mantled by Tertiary deposits. In the extreme northern portion of the county Benton shale outcrops in a small area. The principal water supplies are derived from the lower portion of the alluvial and the Tertiary deposits, though some of the wells penetrate the Dakota sandstone and obtain good waters at moderate depths. So far as known no attempts have been made to sink deeper wells, and as the "Red Beds" lie at no great distance below the surface, are of great thickness, and yield only saline waters, there is no encouragement for deep boring in this county.

Analysis 1, Table 24, is a test of a soft calcic alkaline water from the Tertiary deposits. The other analyses were made in the course of an investigation of the quality of ground water in the vicinity of Kinsley. They demonstrate that most of the waters in the locality are unsatisfactory for use in boilers. Analyses 8, 10, and 13 show good soft alkaline waters, and analysis 12 indicates a hard calcic alkaline saline water. Analyses 3, 4, 5, and 6 are tests of sodic saline waters. Analysis 7 shows a calcic magnesic saline water. Analyses 11 and 14 to 22 demonstrate calcic sodic saline waters. Analyses 2 and 9 show highly mineralized sodic calcic magnesic saline waters. Calcic sodic saline waters are characteristic of the underflow of Arkansas River. As these waters of the underflow are high in sodium, magnesium, and sulphates, they are laxative in their effect on those unaccustomed to their use, but within the river valley they are used for public water supplies and apparently have no therapeutic effect on the citizens.

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[1] Description abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 295.

TABLE 24.—*Analyses and assays of underground waters from Edwards County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| | 1902. | | | | | | | | | | | | | | |
| 1 | Oct. 19 | Belpre, surface well | ........ | Atchison, Topeka & Santa Fe Ry. | 16 | 2.2 | 55 | 3.7 | 24 | 96 | ........ | 23 | 15 | ........ | ........ |
| | 1897. | | | | | | | | | | | | | | |
| 2 | Aug. 5 | Kinsley, well No. 1 | ........ | do | 43 | ...... | 163 | 88 | 268 | 151 | ........ | 822 | 173 | 57 | 1,763 |
| 3 | ...do..... | Kinsley, well No. 2 | ........ | do | 17 | ...... | 46 | 12 | 148 | 30 | ........ | 110 | 227 | 67 | 668 |
| 4 | ...do..... | Kinsley, well No. 3 | ........ | do | 21 | ...... | 66 | 38 | 323 | 60 | ........ | 667 | 32 | 50 | 1,256 |
| 5 | June 16 | Kinsley, well No. 299 | ........ | do | 60 | ...... | 127 | 97 | 951 | 275 | ........ | 298 | 1,414 | 212 | 3,433 |
| | 1898. | | | | | | | | | | | | | | |
| 6 | June 17 | Kinsley, new well | ........ | do | 20 | ...... | 45 | 18 | 127 | 78 | ........ | 133 | 138 | 58 | 625 |
| 7 | Aug. 30 | Kinsley, test well | ........ | do | 15 | ...... | 134 | 69 | 66 | 165 | ........ | 335 | 102 | 106 | 994 |
| 8 | Feb. 24 | Kinsley, B. W. Morris's well 2¾ miles south of Kinsley on sec. 10. | ........ | do | ........ | ...... | 30 | ........ | 11 | 37 | ........ | 13 | 17 | 32 | 135 |
| 9 | ...do..... | Kinsley, city waterworks well | 25 | do | ........ | ...... | 109 | 39 | 127 | 98 | ........ | 380 | 110 | 123 | 984 |
| | 1900. | | | | | | | | | | | | | | |
| 10 | Oct. 21 | Kinsley, test hole No. 3, mile post 299. | 32 | do | ........ | ...... | 59 | ........ | 5.5 | 81 | ........ | 18 | 4.1 | 19 | 185 |
| 11 | Oct. 29 | Kinsley, No. 1, Arkansas River bed. | ........ | do | ........ | ...... | 162 | 35 | 109 | 72 | ........ | 576 | 47 | 51 | 1,056 |
| 12 | ...do..... | Kinsley, No. 2, hole in sand | ........ | do | ........ | ...... | 58 | 9.4 | 20 | 70 | ........ | 82 | 14 | 19 | 274 |
| 13 | Oct. 31 | Kinsley, No. 3, prospect hole | 26 | do | ........ | ...... | 61 | ........ | 2.7 | 81 | ........ | 9.7 | 8.6 | 17 | 183 |
| | 1902. | | | | | | | | | | | | | | |
| 14 | Oct. 22 | Kinsley, artesian well | ........ | do | ........ | ...... | 130 | 28 | 120 | 87 | ........ | 469 | 45 | 15 | ........ |
| | 1903. | | | | | | | | | | | | | | |
| 15 | Mar. 31 | Kinsley, artesian well | ........ | do | 15 | ...... | 151 | 31 | 101 | 105 | ........ | 466 | 46 | 98 | 1,013 |
| 16 | June 30 | Kinsley, east well | ........ | do | 17 | 9.6 | 171 | 15 | 155 | 35 | ........ | 661 | 48 | 95 | 1,212 |
| 17 | Oct. 20 | Kinsley, east well | ........ | do | 6.8 | 1.2 | 132 | 30 | 143 | 68 | ........ | 535 | 68 | 79 | 1,063 |
| 18 | May 13 | Kinsley, east well, 17 feet below surface. | ........ | do | 12 | ...... | 145 | 34 | 112 | 89 | ........ | 517 | 42 | 116 | 1,068 |
| 19 | Oct. 20 | Kinsley, middle well, at river | ........ | do | 8.6 | ...... | 148 | 32 | 121 | 56 | ........ | 576 | 51 | 60 | 1,046 |
| 20 | May 13 | Kinsley, middle well, at 15 feet | ........ | do | 15 | ...... | 168 | 31 | 128 | 114 | ........ | 495 | 48 | 137 | 1,130 |
| 21 | Oct. 20 | Kinsley, west well, at river | ........ | do | 12 | 3.6 | 158 | 32 | 124 | 113 | ........ | 515 | 51 | 128 | 1,139 |
| 22 | May 13 | Kinsley, west well, at 17 feet | ........ | do | 12 | ...... | 109 | 25 | 95 | 80 | ........ | 362 | 49 | 101 | 832 |
| | | ASSAYS. | | | | | | | | | | | | | |
| | 1907. | | | | | | | | | | | | | | |
| 1 | Nov. 30 | Kinsley, well of Kirby A. Little, Ninth Avenue near Tenth Street. | 35 | ........ | ........ | .0 | ...... | ........ | ........ | .0 | 178 | 181 | 36 | ........ | ........ |
| 2 | ...do..... | Kinsley, city waterworks well | 25 | ........ | ........ | .0 | ...... | ........ | ........ | .0 | 278 | 570 | 166 | ........ | ........ |

## ELK COUNTY.

Elk County is underlain by Pennsylvanian rocks, therefore hard waters may be expected. No water assays were made of the ground waters in this county, nor are there any analyses of these waters available for publication.

## ELLIS COUNTY.

Ellis County is underlain mainly by the Benton rocks, but the high divides to the west are capped by the rocks of the Niobrara formation and some Tertiary deposits. The Dakota sandstone lies at a moderate depth, averaging from 300 to 400 feet through the greater part of the county, but increasing to over 500 feet in the highest lands to the west and diminishing to less than 200 feet in the deeper valleys to the east and south. The rocks dip gently to the north. A number of wells have been sunk to the Dakota sandstone, but no reports have yet been obtained as to their results.

In 1903 a boring was sunk on Smoky Hill River, 15 miles due southwest of Hays, on the S. ½ sec. 10, T. 15 S., R. 20 W., a depth of 1,777 feet being reached. The drill passed through the Benton shales and Dakota sandstone into the "Red Beds," which were reached at a depth of 628 feet. Considerable water, which rose within 70 feet of the surface, was found at the top of a thick bed of sandstone, presumably Dakota, at a depth of 215 feet. Near the bottom of this sandstone, at a depth of 500 feet, there was a strong artesian flow of fresh water, which is still flowing vigorously and under sufficient pressure to rise 15 inches above the top of the casing. Artesian salt water was found a short distance below, and at intervals to a depth of 993 feet.[1]

Assay 3, Table 25, shows the quality of water from the gypsiferous shales of the Dakota and assay 8 that of a water from the gypsiferous and saliferous shales of the Dakota. Both waters are very hard and that from the saliferous shales has a salty taste. Assays 2 and 7 indicate waters having high temporary and permanent hardness. The other assays recorded in the table represent tests of well waters in the valley of Big Creek and show that these have high temporary and little permanent hardness.

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 295.

TABLE 25.—*Assays of underground waters from Ellis County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | 1907. | | | | | | | |
| 1 | Sept. 20 | Ellis, well of R. R. Davidson, Washington Street [a] | 37 | Tr. | 0.0 | 262 | Tr. | 15 |
| 2 | ...do..... | Ellis, well at rear of drug store on north side of Main Street | 30 | 0.0 | .0 | 367 | 406 | 88 |
| 3 | ...do..... | Ellis, well of J. P. Riedel, 9 miles northeast of city, on sec. 21, T. 12 S., R. 19 W. [b] | 523 | .0 | .0 | 300 | 460 | 39 |
| 4 | Sept. 19 | Hays, well of Windsor Hotel, Chestnut Street | 30 | .0 | .0 | 344 | Tr. | 15 |
| 5 | ...do..... | Hays, points of city waterworks, tap in Hotel Brunswick. | 35 | .0 | .0 | 312 | Tr. | 24 |
| 6 | ...do..... | Hays, Ryan well | {35(?) 60(?)} | 1.5 | .0 | 317 | (c) | 566 |
| 7 | ...do..... | Hays, well at Agricultural Experiment Station | 32 | .0 | .0 | 369 | 65 | 30 |
| 8 | ...do..... | Hays, well of Kaspar Leiker, 7 miles southeast of city, on NW. ¼ sec. 27, T. 14 S., R. 18 W. [d] | 245 | .0 | .0 | 377 | 287 | 722 |

[a] On north of Big Creek, where water is locally believed to be better than on south side.
[b] Sunk in 1902. Water rose to 512 feet. Well cased full depth and derives water from Dakota sandstone.
[c] $SO_4$ greater than 626.
[d] A few miles east of this well Mr. Stoner, Kaspar Klaus, and others have wells of about the same depth.

## ELLSWORTH COUNTY.

The Dakota sandstone is at or near the surface throughout Ellsworth County, except in the deeper portion of Smoky Hill Valley to the southeast, where the underlying Permian rocks are cut into. The sandstone affords a water supply, in most places of satisfactory quality, for many wells of various depths. On some of the lower lands between Ellsworth and Black Wolf the water flows in small volume in wells which reach the lower sandstone of the Dakota formation.

At Palacky, where the Benton shale is the surface formation, a well 336 feet deep obtains a large supply of slightly salty water, which rises to within 176 feet of the surface. In the northeastern corner of T. 14, R. 9, which is also on the Benton shale, a well 384 feet deep obtains a small supply of fine water, which does not rise materially in the well, at a depth of 170 feet. As a number of borings in this county have penetrated deeply into the Permian rocks underlying the Dakota sandstone and found only salt water, it is probable that fresh artesian waters are not obtainable.[1]

In Table 26 calcic alkaline waters are shown by analyses 1, 2, and 9, and a sodic calcic alkaline water is indicated by analysis 5. A calcic saline water is denoted by analysis 6 and a calcic sodic saline water by analysis 8. Sodic calcic saline waters are demonstrated by analyses 3, 7, and 10. Assay 1 indicates that the old public water supply of Ellsworth, which is derived from several underground sources, has high temporary hardness and is low in sulphates. Assay 2 shows a very hard water. Assay 3, one of high temporary and low permanent hardness, and assay 4 indicates a water that is highly mineralized and rich in chlorides.

[1] Description abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 296.

TABLE 26.—*Analyses and assays of underground waters from Ellsworth County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1908. Mar. 9 | Arcola, spring | ........ | Union Pacific R. R. | 27 | 4.4 | 66 | 17 | 29 | 97 | ........ | 112 | ........ | 15 | 369 |
| 2 | 1901. Nov. 21 | Ellsworth, city waterworks well on hill, 900 feet northwest of pumping station. | 24 | Dearborn Laboratories[a] | 27 | 3.2 | 78 | 5 | 28 | 129 | ........ | 35 | ........ | 17 | ........ |
| 3 | Oct. 7 | Ellsworth, points at edge of Smoky Hill River west of mill. | ........ | Union Pacific R. R. Co.[a] | 31 | 6.1 | 181 | 34 | 219 | 180 | ........ | 323 | ........ | 306 | ........ |
| 4 | Oct. 10 | Ellsworth, well at United States Elevator & Cold Storage Co. | ........ | do[a] | 37 | 2.5 | 129 | 61 | 182 | 193 | ........ | 264 | ........ | 266 | ........ |
| 5 | Dec. 15 | Ellsworth, from 4 points | ........ | do[a] | 30 | 2.2 | 128 | 12 | 158 | 149 | ........ | 80 | ........ | 270 | ........ |
| 6 | Dec. 20 | Ellsworth, well 460 feet east of tank | ........ | do[a] | 37 | 3.9 | 139 | 10 | 30 | 120 | ........ | 183 | ........ | 46 | ........ |
| 7 | 1907. June 1 | Ellsworth, Chas. Robinson's well | 30 | E. H. S. Bailey[a] | 20 | 59 | 222 | 31 | 414 | 246 | ........ | 272 | ........ | 638 | ........ |
| 8 | 1908. July 27 | Ellsworth, 2 wells, 2,000 feet east of station. | 43 | Union Pacific R. R. | 23 | 3.1 | 146 | 0 | 102 | 181 | ........ | 131 | ........ | 105 | 692 |
| 9 | 1907. July 19 | Ellsworth, well, proposed new city supply. | ........ | F. W. Bushong[b] | 40 | .8 | 152 | 20 | ........ | .0 | 448 | 97 | 57 | 104 | 686 |
| 10 | 1902. Sept. 23 | Holyrood, well | ........ | Atchison, Topeka & Santa Fe Ry. | 27 | .7 | 68 | 6.2 | 78 | 167 | ........ | 32 | ........ | 36 | ........ |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Sept. 16 | Ellsworth, old city supply wells and filter galleries. | 24–35 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 312 | Trace. | ........ | 24 | ........ |
| 2 | ...do... | Ellsworth, Union Pacific R. R. well. | 43 | ........ | ........ | 1.0 | ........ | ........ | ........ | .0 | 377 | 90 | ........ | 114 | ........ |
| 3 | Sept. 17 | Ellsworth, well at Cemetery Lodge, south of Smoky Hill River. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 317 | Trace. | ........ | 14 | ........ |
| 4 | ...do... | Ellsworth, flowing well in cemetery, south side Smoky Hill River. | [c]165 | ........ | ........ | Tr. | ........ | ........ | ........ | .0 | 350 | 362 | ........ | 1,411 | ........ |

[a] Analyses furnished by Ellsworth Salt Co.
[b] Analyses made at the laboratories of the University of Kansas.
[c] Water struck at 125 feet.

## FINNEY COUNTY.

Finney County comprises a region of high plains in its northern part, a portion of Arkansas Valley across its center, and an extensive district of plains and sand hills in the south. The only running water is Arkansas River and some small streams in the headwaters of Pawnee Creek. Springs are very rare. Shallow wells obtain variable supplies from Tertiary deposits, valley alluvium, and dune sands. Some deeper wells reach Dakota sandstone, which underlies the county at a depth of 200 feet in the southern portion, 400 feet at Garden, and 1,000 feet or more in the northern and northwestern portions. In the northeast corner the Dakota sandstone has been reached by several wells about 400 feet deep and a large supply of water found. The quality, however, has been somewhat variable and at some localities is too salty for use. It rises considerably but does not reach the surface. A well at Kalvesta, 355 feet deep, failed to reach the top of the Dakota sandstone. In a boring half a mile northwest of Garden it is claimed that a depth of over 1,000 feet was reached without obtaining a satisfactory supply. The record is somewhat difficult to interpret, but apparently the boring entered the Dakota sandstone at a depth of 460 feet and continued in it for 250 or 300 feet. Two wells, 400 feet or more in depth, are reported north of Ravenna, in the northeastern corner of the county. They found water in shales, but its quality was unsatisfactory.[1]

In the valley of Arkansas River the "underflow" of the river feeds many wells. This underflow is believed to have its source in the rain that falls on the sand dunes south of the river and that is making its way southeastward beneath the river. Water taken at the top of this underflow is high in sulphates, whereas water taken deeper down in it is usually less heavily loaded with them.

Analyses 1 to 15, Table 27, are tests of waters about Garden. Of these soft calcic alkaline waters from wells south of the river at Garden are shown by analyses 7, 8, and 9, and a calcic alkaline water of fair quality from an artesian well is indicated by analysis 13. Soft calcic sodic alkaline waters from wells in the sand hills south of the river are shown by analyses 10 and 11, and calcic sodic alkaline waters from artesian wells are shown to be somewhat high in sulphates by analyses 12 and 15. A laxative sodic calcic magnesic alkaline water from an artesian well is shown by analysis 14. A hard calcic magnesic saline water is indicated by analysis 3, a highly mineralized calcic magnesic sodic saline water by analysis 2, and an unsatisfactory calcic sodic magnesic saline water by analysis 1. A highly mineralized sodic calcic saline water is shown by analyses 5 and 6. A highly mineralized sodic calcic magnesic

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 297.

saline water is demonstrated by analysis 4. Analyses 16 to 21 show the quality of ground waters in the vicinity of Pierceville. Of these soft calcic alkaline waters are shown by analyses 17 and 19. A soft calcic sodic alkaline water is denoted by analysis 18. Calcic sodic magnesic alkaline waters high in sulphates are shown by analyses 16 and 20. An unsatisfactory calcic sodic magnesic saline water is marked by analysis 21. Assay 1 is a test of a well in the shallow valley northeast of Garden and shows the water to have a very high temporary hardness. The ground near the well had been plowed and looked as though it was covered with frost, so abundant was the white alkali. The valley is probably an old course of White Woman Creek. Assays 2, 3, 4, 5, 6, 7, and 11 are tests of the waters of shallow wells that tap the upper portion of the underflow. These waters are high in sulphates. Assays 8, 9, 10, and 12 show the quality of the waters of wells that extend down deeper into the underflow, thereby getting less highly mineralized waters.

TABLE 27.—*Analyses and assays of underground waters from Finney County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | |
| | 1898. | | | | | | | | | | | |
| 1 | Oct. 25 | Garden, J. Craig's well north of city | | Atchison, Topeka & Santa Fe Ry. | 66 | 27 | 71 | 113 | 190 | 30 | 50 | 546 |
| 2 | ...do.... | Garden, J. A. Stephen's well west of city | | ....do | 240 | 117 | 192 | 173 | 1,060 | 77 | 279 | 2,140 |
| 3 | ...do.... | Garden, railroad tanks, city water well | 34 | ....do | 119 | 36 | 53 | 138 | 291 | 19 | 79 | 736 |
| 4 | ...do.... | Garden, J. L. Dresvins's well at home | | ....do | 68 | 34 | 92 | 137 | 236 | 28 | 67 | 662 |
| 5 | Oct. 27 | Garden, D. R. Menkes's well—bottom | | ....do | 62 | 20 | 82 | 114 | 184 | 24 | 55 | 544 |
| 6 | ...do.... | Garden, D. R. Menkes's well—bottom and top mixed | | ....do | 142 | 33 | 213 | 145 | 609 | 55 | 132 | 1,330 |
| 7 | Oct. 25 | Garden, M. Marshall's well, south bank of river | | ....do | 57 | 7.4 | 16 | 104 | 17 | 11 | 22 | 238 |
| 8 | ...do.... | Garden, J. A. Ballard's well, south of city in sand hills | | ....do | 57 | 8.9 | 20 | 107 | 29 | 9 | 27 | 262 |
| 9 | ...do.... | Garden, S. A. Ballard's well at sand hills | | ....do | 75 | 9.8 | 24 | 148 | 20 | 10 | 67 | 354 |
| 10 | Dec. 7 | Garden, J. C. Thomas's well, 700 feet south of south bank of Arkansas River, near sand hills. | 16 | ....do | 58 | 11 | 6.7 | 100 | 23 | 10 | 24 | 233 |
| 11 | ...do.... | Garden, J. C. Thomas's well, 3 miles south of river in sand. | 32 | ....do | 25 | 6.4 | 14 | 57 | 8.1 | 12 | 20 | 144 |
| 12 | ........ | Garden, 2 artesian wells | 130 | ....do | 49 | 8.4 | 29 | 83 | 68 | 7.3 | 27 | 272 |
| 13 | ........ | Garden, artesian well | | ....do | 49 | 12 | 21 | 84 | 59 | 12 | 18 | ........ |
| | 1899. | | | | | | | | | | | |
| 14 | Jan. 9 | ....do | 350 | ....do | 34 | 20 | 75 | 137 | 76 | 17 | 36 | 395 |
| | 1900. | | | | | | | | | | | |
| 15 | May 14 | Garden, well | 86 | ....do | 54 | 7.9 | 36 | 86 | 77 | 15 | 32 | 313 |
| | 1898. | | | | | | | | | | | |
| 16 | Feb. 21 | Pierceville, well at section house | | ....do | 64 | 18 | 43 | 112 | 108 | 20 | 32 | 397 |
| 17 | Oct. 25 | Pierceville, well of A. J. Logan | | ....do | 62 | 6 | 11 | 104 | 8.5 | 18 | 51 | 262 |
| 18 | ...do.... | Pierceville, well of A. J. Logan at foot of sand hills in river bottom. | | ....do | 75 | 8.4 | 37 | 140 | 24 | 31 | 19 | 336 |
| 19 | Oct. 27 | Pierceville, exploring well in sand hills 1¼ miles south of city. | | ....do | 70 | 4.4 | 26 | 116 | 41 | 7.3 | 20 | 288 |
| 20 | Nov. 26 | Pierceville, J. G. Grubb's well | | ....do | 70 | 16 | 47 | 113 | 117 | 24 | 33 | 419 |
| 21 | Dec. 26 | Pierceville, G. W. Wallace's well opposite depot | | ....do | 79 | 21 | 57 | 114 | 167 | 30 | 39 | 507 |

TABLE 27.—*Analyses and assays of underground waters from Finney County*—Continued.

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1907. | | | | | | | |
| 1 | Nov. 25 | Garden, well on southeast corner of SW. ¼ sec. 20, T. 23 S., R. 32 W. [a] | 2⅓ | 0.0 | 0.0 | 590 | 626 | 104 |
| 2 | ...do.... | Garden, well of A. H. Eggin on N. ½ of SW. ¼ sec. 32, T. 23 S., R. 32 W. | .......... | .0 | .0 | 254 | (b) | 393 |
| 3 | ...do.... | Garden, well of G. L. Holmes, NE. ¼ sec. 22, T. 24 S., R. 32 W. | 12 | .0 | .0 | 267 | (b) | 67 |
| 4 | ...do.... | Garden, well of G. L. Holmes, southeast corner of NE. ¼ sec. 22, T. 24 S., R. 32 W. | 38 | .0 | .0 | 306 | (b) | 83 |
| 5 | Nov. 23 | Garden, well of W. E. Covert | 20 | .0 | .0 | 262 | 626 | 56 |
| 6 | Nov. 24 | Garden, well of D. H. Holcomb Cattle Co. [c] | .......... | 0 | .0 | 200 | 626 | 67 |
| 7 | Nov. 22 | Garden, city waterworks well. [d] | 20 | 0 | .0 | 272 | 626 | 46 |
| 8 | ...do.... | Garden, well of O. L. Helwig, Chestnut and North Seventh Streets | 108 | .0 | .0 | 178 | 66 | 15 |
| 9 | ...do.... | Garden, well of A. H. Burtis, 412 North Seventh Street | [e] 108 | .0 | .0 | 178 | 66 | 15 |
| 10 | ...do.... | Garden, 2 wells of Atchison, Topeka & Santa Fe Ry. | 130 | .0 | .0 | 168 | 61 | 15 |
| 11 | ...do.... | Garden, canal fed by 25 shallow wells of United States Sugar & Land Co. [f] | 62 | .0 | .0 | 250 | 530 | 46 |
| 12 | ...do.... | Garden, well of United States Sugar & Land Co. | 184 | .0 | .0 | 168 | 58 | 15 |

[a] An open well in the "Shallow Valley," 13 inches to water level.
[b] $SO_4$ greater than 626.
[c] This well supplies one of the largest private irrigating systems at Garden.
[d] A 14-inch perforated pipe extends 30 feet below bottom of well.
[e] About.
[f] At time sample was taken 11 wells were being pumped at a rate of 3,000,000 gallons in 24 hours.

## FORD COUNTY.

Dakota sandstone underlies the southeastern half of Ford County, and Benton shale the northwestern half. Both formations are extensively covered by Tertiary deposits on the higher lands and by alluvium and dune sands along the Arkansas. Shallow wells obtain water supplies from the younger formations, and some wells in the eastern part of the county reach the water in the Dakota sandstone. No artesian flows are promised in this county, unless possibly from the "Red Beds" which underlie the Dakota sandstone, and the waters of these rocks are invariably salty. The formations below the "Red Beds" might present different conditions, but probably lie too deep for ordinary well borings. It is said that in 1886 a boring for coal, 1,000 feet deep, was made at Dodge, but that it found neither coal nor water, and undoubtedly ended in the "Red Beds." [1]

In Table 28, analyses 1 and 2 represent tests of a soft calcic alkaline water at Bucklin; analyses 3 to 38 record tests of ground water around Dodge. The water tested by analyses 7, 9, 10, 18, 19, and 26 belong to the calcic alkaline class and are of good quality; calcic alkaline waters of fair quality are represented by analyses 15, 20, 31, and 32, and calcic alkaline waters of poor quality for use in boilers are indicated by analyses 9, 24, 25, 28, 30, and 38. Calcic sodic alkaline waters of good quality are represented by analyses 12 and 13; calcic sodic alkaline waters of fair quality are indicated by analyses 29 and 37. A calcic sodic alkaline water of poor quality is exhibited by analysis 23. Calcic magnesic alkaline waters of good quality are indicated by analyses 33 and 34; waters of the same class but of fair quality are represented by analyses 11, 16, and 35. A poor water of this same class is shown by analysis 36. A sodic calcic alkaline water of poor quality is indicated by analysis 14. Calcic saline waters of poor quality are represented by analyses 5, 6, and 17, and a calcic saline water of very bad quality by analysis 4. Calcic sodic saline waters of poor quality are indicated by analyses 21 and 22. Tests of two soft calcic alkaline waters at Spearville are recorded in analyses 39 and 40.

The assays represent tests of two wells of the Midland Water, Light & Ice Co. These wells are near together and yield water like in composition, which is unusual in wells that tap the Arkansas River underflow and differ in depth as greatly as do these two.

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[1] Abstract from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 298.

TABLE 28.—*Analyses and assays of underground waters from Ford County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1903. Feb. 2 | Bucklin, artesian well | ........ | Chicago, Rock Island & Pacific Ry. | 11 | 4.5 | 68 | 16 | 10 | 130 | ........ | 23 | 12 | ........ | ........ |
| 2 | 1908. Sept. | Bucklin, well | 120 | ....do | ........ | *a* 7.2 | 80 | 18 | 13 | 140 | ........ | 34 | 25 | ........ | 317 |
| 3 | 1897. Apr. 10 | Dodge, Atchison, Topeka & Santa Fe Ry. well. | ........ | Atchison, Topeka & Santa Fe Ry. | 48 | 50 | 132 | 116 | 71 | 236 | ........ | 208 | 249 | 111 | 1,075 |
| 4 | 1898. Nov. 19 | Dodge, R. McLeall's well | ........ | ....do | ........ | ........ | 241 | 5.4 | 76 | 146 | ........ | 245 | 207 | 250 | 1,174 |
| 5 | ...do... | Dodge, H. E. Clark's well | ........ | ....do | ........ | ........ | 106 | 16 | 64 | 130 | ........ | 206 | 29 | 46 | 602 |
| 6 | ...do... | Dodge, E. M. Carpenter's well | ........ | ....do | ........ | ........ | 96 | 18 | 40 | 102 | ........ | 180 | 29 | 58 | 531 |
| 7 | Nov. 14 | Dodge, C. M. Beesom's well, 3 miles south on land higher than river bottom. | ........ | ....do | ........ | ........ | 65 | 11 | 16 | 119 | ........ | 19 | 18 | 27 | 276 |
| 8 | ...do... | Dodge, G. E. McKinney's well, 1 mile east of Beesom's well. | ........ | ....do | ........ | ........ | 115 | 14 | 66 | 95 | ........ | 278 | 30 | 48 | 647 |
| 9 | ...do... | Dodge, H. R. Moreon's well, 5½ miles south on high land. | ........ | ....do | ........ | ........ | 67 | 11 | 23 | 124 | ........ | 38 | 12 | 32 | 308 |
| 10 | ...do... | Dodge, spring in Duck Creek, 5½ miles north. | ........ | ....do | ........ | ........ | 69 | 14 | 12 | 137 | ........ | 14 | 10 | 27 | 284 |
| 11 | 1899. Feb. 6 | Dodge, H. Janeau's well, 700 feet east of depot. | 24 | ....do | ........ | ........ | 73 | 23 | 37 | 152 | ........ | 58 | 30 | 96 | 467 |
| 12 | May 26 | Dodge, well | 50 | ....do | ........ | ........ | 66 | 9.4 | 44 | 95 | ........ | 92 | 28 | 92 | 426 |
| 13 | Jan. 28 | Dodge, F. Hobble's well, on high ground one-half mile north of railway tank. | 85 | ....do | ........ | ........ | 74 | 6.9 | 58 | 171 | ........ | 30 | 17 | 44 | 401 |
| 14 | July 7 | Dodge, well No. 1 | 85 | ....do | ........ | ........ | 64 | 23 | 105 | 188 | ........ | 36 | 95 | 118 | 635 |
| 15 | Mar. 23 | Dodge, well one-fourth mile north of coal chutes. | ........ | ....do | ........ | ........ | 116 | 3.5 | 7.4 | 145 | ........ | 12 | 48 | 144 | 493 |
| 16 | Jan. 28 | Dodge, Stubb's well, 2 miles east of city near Atchison, Topeka & Santa Fe Ry. tracks. | 140 | ....do | ........ | ........ | 69 | 24 | 11 | 146 | ........ | 27 | 17 | 68 | 361 |
| 17 | ...do... | Dodge, C. M. Beesom's well, 200 feet south and 300 feet east of NW. corner sec. 2, south side of river. | 27 | ....do | ........ | ........ | 129 | 21 | 30 | 133 | ........ | 200 | 30 | 99 | 643 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | ...do.... | Dodge, H. B. Ball's well, 500 feet east-north of SW. corner sec. 3, south side of river, high ground. | 58 | .....do........ | ........ | ........ | 62 | 8.4 | 22 | 114 | ......... | 22 | 18 | 39 | 286 |
| 19 | ...do..... | Dodge, G. F. McKenney's home well, NW. ¼ sec. 6, south side of river. | 14 | .....do........ | ........ | ........ | 63 | 9.4 | 15 | 99 | ......... | 37 | 17 | 32 | 272 |
| 20 | ...do..... | Dodge, exploring well, 80 feet north and 1,200 feet east of SW. corner sec. 34, south side of river. | 21 | .....do........ | ........ | ........ | 95 | 14 | 32 | 141 | ......... | 101 | 18 | 60 | 460 |
| 21 | ...do..... | Dodge, H. Wray's well, SW. corner of SE. ¼ sec. 35, south side of river. | 12 | .....do........ | ........ | ........ | 110 | 23 | 88 | 150 | ......... | 247 | 37 | 72 | 726 |
| 22 | ...do..... | Dodge, R. Robbins's well, 600 feet east of Carpenter's well, south of Chicago, Rock Island & Pacific Ry., SE. ¼ sec. 35, south side of river. | ........ | .....do........ | ........ | ........ | 105 | 17 | 49 | 131 | ......... | 167 | 34 | 96 | 599 |
| 23 | ...do..... | Dodge, exploring well, 400 feet north of Chicago, Rock Island & Pacific Ry. and 100 feet east of west line 36, south side of river. | ........ | .....do........ | ........ | ........ | 150 | 19 | 109 | 228 | ......... | 253 | 33 | 96 | 888 |
| 24 | ...do..... | Dodge, exploring well, 400 feet north of Chicago, Rock Island & Pacific Ry. and 100 feet east from SW. corner of sec. 36, south side of river; sample taken at depth of 18 feet. | ........ | .....do........ | ........ | ........ | 120 | 14 | 20 | 140 | ......... | 132 | 23 | 72 | 522 |
| 25 | ...do..... | Dodge, exploring well, 500 feet north and 1,600 feet east of SW. corner of sec. 36; sample taken at depth of 17 feet. | ........ | .....do........ | ........ | ........ | 138 | 16 | ........ | 154 | ......... | 156 | 19 | 92 | 575 |
| 26 | ...do..... | Dodge, exploring well, 700 feet north and 100 feet east from SW. corner sec. 36, south side of river. | ........ | .....do........ | ........ | ........ | 71 | 12 | 28 | 127 | ......... | 48 | 18 | 50 | 351 |
| 27 | ...do..... | Dodge, exploring well, 800 feet east of west line sec. 36, and 1,600 feet north of Chicago, Rock Island & Pacific Ry., 500 feet south of river. | ........ | .....do........ | ........ | ........ | 212 | 38 | 104 | 147 | ......... | 563 | 57 | 135 | 1,257 |
| 28 | Feb. 3 | Dodge, No. 26 exploring well, 1,300 feet north and 1,600 feet east of SW. corner sec. 36; sample taken at 10 feet. | ........ | .....do........ | ........ | ........ | 130 | 18 | 28 | 188 | ......... | 112 | 20 | 103 | 602 |
| 29 | ...do..... | Dodge, exploring well, 300 feet south and 2,700 feet east of SW. corner sec. 36; sample taken at 20 feet. | ........ | .....do........ | ........ | ........ | 88 | 14 | 58 | 173 | ......... | 95 | 10 | 75 | 514 |
| 30 | Jan. 28 | Dodge, exploring well, 80 feet west and 1,200 feet east of SW. corner sec. 38, south side of river; sample taken at 7 feet. | ........ | .....do........ | ........ | ........ | 126 | 16 | 44 | 214 | ......... | 90 | 17 | 60 | 567 |

*a* $SiO_2 + Fe_2O_3 + Al_2O_3$.

TABLE 28.—*Analyses and assays of underground waters from Ford County*—Continued.

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES—continued. | | | | | | | | | | | | | |
| 31 | 1900. Apr. 20 | Dodge, well No. 4 | 116 | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 71 | 17 | 23 | 136 | ........ | 45 | 18 | 39 | 351 |
| 32 | Apr. 24 | ....do | 146 | ....do | ........ | ........ | 71 | 16 | 24 | 142 | ........ | 36 | 16 | 44 | 354 |
| 33 | Dec. 5 | Dodge, tubular well | ........ | ....do | ........ | ........ | 59 | 22 | 20 | 126 | ........ | 36 | 23 | 39 | 325 |
| 34 | Feb. 5 | Dodge, deep wells of Atchison, Topeka & Santa Fe Ry. | ........ | ....do | 36 | ........ | 58 | 21 | 8.9 | 114 | ........ | 36 | 15 | 74 | ........ |
| 35 | 1904. Aug. 6 | Dodge, surface well | ........ | ....do | 46 | 1.2 | 56 | 24 | 21 | 118 | ........ | 46 | 28 | 92 | 433 |
| 36 | 1908. Sept. | Dodge, well | 60 | Chicago, Rock Island & Pacific Ry. | ........ | a 8.2 | 90 | 28 | 24 | 154 | ........ | 83 | 34 | ........ | 422 |
| 37 | ........ | Dodge, Frank Hubble's well | 58 | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 73 | 6.9 | 57 | 170 | ........ | 29 | 17 | 43 | 401 |
| 38 | ........ | Dodge, exploring well, 80 feet north and 1,200 feet east of SW. corner sec. 36; sample taken at 4 feet below surface. | ........ | ....do | ........ | ........ | 126 | 15 | 43 | 213 | ........ | 88 | 17 | 58 | 567 |
| 39 | 1902. Oct. 30 | Spearville, surface well | ........ | ....do | 48 | ........ | 62 | 17 | 13 | 115 | ........ | 20 | 30 | ........ | ........ |
| 40 | May 14 | Spearville, well | 91 | ....do | ........ | ........ | 74 | 14 | 14 | 131 | ........ | 17 | 26 | 27 | 303 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Nov. 20 | Dodge, well of Midland Water, Light & Ice Co. | 18 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 211 | 58 | 26 | ........ | ........ |
| 2 | ...do | ....do | 130 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 217 | 50 | 20 | ........ | ........ |

a $SiO_2+Fe_2O_3+Al_2O_3$.

## FRANKLIN COUNTY.

Franklin County is entirely underlain by Pennsylvanian rocks which may be expected to yield hard waters.

The only analysis (Table 29) is a test of a water high in calcium, magnesium, and sulphates. Assays 1 and 2 show waters of great temporary and permanent hardness that are high in chlorides. Assays 4 and 5 show water of great temporary and permanent hardness that are low in chlorides, and assay 3 is a test of a water of great permanent hardness, but one that is somewhat lower in bicarbonates than the others.

TABLE 29.—*Analysis and assays of underground waters from Franklin County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | .......... | Williamsburg, bored well of F. H. Welsh.[a] | ... | E. H. S. Bailey and D. F. McFarland. | 67 | 11 | 916 | 485 | 156 | .... | .... | 2,979 | 202 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1905. June 19 | Ottawa, Shaner House well. | 32 | .................. | ... | Tr. | .... | .... | .... | 0.0 | 427 | 460 | 331 |
| 2 | ...do..... | Ottawa, Rohbau well, one-half block north of courthouse. | 32 | .................. | ... | .0 | .... | .... | .... | .0 | 434 | 191 | 244 |
| 3 | ...do..... | Ottawa, Forest Park dug well. | ... | .................. | ... | .5 | .... | .... | .... | .0 | 283 | 300 | 40 |
| 4 | ...do..... | Ottawa, Forest Park bored well. | 26 | .................. | ... | .0 | .... | .... | .... | .0 | 434 | 287 | 60 |
| 5 | ...do..... | Ottawa, Sylvan Spring at edge of Eight Mile Creek. | ... | .................. | ... | .0 | .... | .... | .... | .0 | 399 | 202 | 56 |

[a] Kansas Univ. Geol. Survey, vol. 7, p. 191.

## GEARY COUNTY.

The analyses and assays in the following table represent tests of well waters in the fluviatile deposits of Kansas and Republican rivers and are not typical for water generally found in Geary County, most of which is underlain by Permian rocks.

Analysis 1, Table 30, indicates a very satisfactory water for domestic use, for neither the temporary nor permanent hardness is high. Analysis No. 2 denotes a water having high permanent and very high temporary hardness. The assay shows greater temporary hardness in the water of Junction than is indicated by the analysis.

TABLE 30.—*Analyses and assay of underground waters from Geary County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | 1908. Mar. 5 | Junction, well at city waterworks. | 60 | Union Pacific R. R. | 20 | 0.8 | 77 | 15 | 24 | 141 | .... | 33 | 25 | 336 |
| 2 | 1905. Aug. 30 | Junction, well of the Electric Railway, Light & Ice Co. | 40 | Kennicott Water Softener Co. | 23 | 1.4 | 156 | 23 | 75 | 189 | .... | 82 | 172 | .... |
| | | ASSAY. | | | | | | | | | | | | |
| 1 | 1907. Feb. 26 | Junction, city supply, 13 wells. | 59–62 | .................... | ... | .0 | ... | ... | .... | .0 | 324 | Tr. | 20 | .... |

## GOVE COUNTY.

Gove County extends from Smoky Hill Valley north to the south side of Saline Valley, and comprises a region of high plains intersected by several branches of Smoky Hill River and the head of Big Creek. The highlands are covered by Tertiary deposits, but the valleys have been cut through this mantle and widely expose the underlying Niobrara chalk. The depth to Dakota sandstone ranges from about 600 feet in the southeast corner of the county to slightly over 1,100 feet in the northwest corner, as nearly as can be calculated on the assumption of a thickness of 400 feet of Niobrara formation and 450 feet of Benton formation. A few wells have been sunk in the county which attempted to penetrate the shale, but they were not successful. One well in the southwest corner, 3 miles south of Smoky Hill River, reached a depth of 400 feet, 48 feet of which were reported as surface material, and the remainder of chalk, of which the lower 52 feet were white. At the depth of 400 feet a supply of fine water, reported to amount to 20 barrels per day, was obtained. In the vicinity of Catalpa a well of 400 feet had about the same result. Near Goodwater a well 501 feet deep at a depth of 501 feet obtained a small amount of water. These borings, of course, were all too shallow to reach the Dakota sandstone. It is probable that in the lower lands of this county this sandstone would yield flowing water of moderate volume and of satisfactory quality.[1]

Wallace, Logan, Gove, and Trego counties have a much greater variety of conditions than prevail to the north. Smoky Hill River and its principal tributaries have cut their channels through the Tertiary, but only a short distance into the Cretaceous,

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 298.

and have accumulated so little sand and silt along their valleys that there is but little ground water in the river valleys proper. In this area, perhaps, more than any other part of the State we have the apparently anomalous condition of water being hard to obtain by digging in the river valleys, yet easily obtained in great abundance on the high uplands near by on either side of the river. Though water is not easily obtained by boring in the valleys, good springs, drawing from the general underground supply, frequently exist where the streams have reached the base of the Tertiary.

There is, however, along the branches of the Hackberry, in the vicinity of Gove City and in Smoky Hill Valley southwest of the area about Oakley, a considerable deposit of sand and clay mixed with gravel which is Tertiary in its origin and carries an underflow which is a source of supply to shallow wells. At Gove City the average depth of wells in the southern part of town is about 40 feet and the water which is obtained from them is derived from this underflow. The wells in the northern part of the city often strike the Niobrara without finding water.[1]

The analysis (Table 31) shows a calcic magnesic saline water of low temporary and high permanent hardness. Assay 1, Table 31, indicates a different water from any of the others assayed in that it has considerable permanent hardness. The other assays show that the waters are very much alike and are all soft.

TABLE 31.—*Analysis and assays of underground waters from Gove County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | | | |
| 1 | 1908. Mar. 16 | Grinnell, well 150 feet east of station of Union Pacific R. R. Co. | 130 | Union Pacific R. R. Co. | 37 | 1.3 | 57 | 21 | 16 | 22 | .... | 184 | 24 | 37 | 364 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Sept. 21 | Gove, public well | 44 | | ... | .0 | ... | ... | .... | .0 | 262 | 62 | 30 | .... | .... |
| 2 | ...do.... | Gove, well of Benjamin Bacon, Main Street. | 40 | | ... | .0 | ... | ... | .... | .0 | 257 | Tr. | 15 | .... | .... |
| 3 | ...do.... | Gove, well of J. E. Cavender, 3½ miles north of city on the Grainfield road, sec. 18, T. 12 S., R. 28 W. | 90 | | ... | .0 | ... | ... | .... | .0 | 227 | Tr. | 15 | .... | .... |
| 4 | ...do.... | Grainfield, town well[a] | 135 | | ... | .0 | ... | ... | .... | .0 | 222 | Tr. | 15 | .... | .... |
| 5 | ...do.... | Grainfield, well of L. H. Johnson at north edge of city on sec. 6, T. 11 S., R. 28 W. | 130 | | ... | .0 | ... | ... | .... | .0 | 236 | Tr. | 20 | .... | .... |

[a] Put down in 1903 for a dairy.

## GRAHAM COUNTY.

The high plains of Graham County are thickly covered by Tertiary deposits which are cut through in the valleys of South Fork of Solomon River, of Bow Creek, and of Saline River, which lies a short

[1] From Report of the Board of Irrigation Survey and Experiment to the Legislature of Kansas for 1895 and 1896, pp. 100, 113.

distance south. The Niobrara chalk has a thickness of considerably over 100 feet in the highlands and is underlain by about 400 feet of Benton shales lying on the Dakota sandstone. This sandstone is not more than 500 feet below the surface in the southeast corner of the county, but, with the northeasterly dip of the beds and the rise of the land to the west, is about 1,000 feet deep in the highest ridges between Bow Creek and North Fork of Solomon River.[1]

No complete mineral analyses have been made of waters in Graham County, but seven assays of waters in Hill and one of a well water in Morland are presented in Table 32. Assay 1 is a test of a shallow well of considerable permanent hardness, and assays 2, 3, and 4 are tests of shallow well waters with very little permanent and only moderate temporary hardness. Assays 5, 6, and 7 show the composition of the waters of some deep wells that probably derive their water from the Benton group. All of these deep wells have very great temporary and permanent hardness. So they are less satisfactory for domestic use and for steam boilers than the waters of the shallow wells. Assay 8 shows a shallow well water of considerable permanent hardness.

TABLE 32.—*Assays of underground waters from Graham County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | 1898. | | | | | | | |
| 1 | Sept. 28 | Hill, public well on Main Street | 55 | 0.0 | 0.0 | 272 | 47 | 20 |
| 2 | ...do..... | Hill, well of De Shoup Hotel | ........ | .0 | .0 | 283 | Trace. | 10 |
| 3 | ...do..... | Hill, well of Graham Milling Co | 57 | .0 | .0 | 295 | ...do.. | 10 |
| 4 | ...do..... | Hill, well of E. V. Cumberford | 48 | .0 | .0 | 277 | ...do.. | 20 |
| 5 | ...do..... | Hill, well of Rollow Photographic Gallery, Pomroy Street | [a] 300 | .0 | .0 | 462 | 246 | 88 |
| 6 | ...do..... | Hill, well of S. N. Coder, Main Street [b] | 314 | .0 | .0 | 382 | 313 | 46 |
| 7 | ...do..... | Hill, well of E. V. Cumberford [c] | 395 | .0 | 21 | 385 | 313 | 57 |
| 8 | ...do..... | Morland, well in livery barn of Charles Green | 12 | 0 | .0 | 267 | 65 | 36 |

[a] About.
[b] Sunk in July, 1907; water rose within 100 feet of surface.
[c] Water rose within 100 feet of surface.

## GRANT COUNTY.

Grant County extends from the valley of the Cimarron up the divide between that river and the Arkansas. The surface is covered by Tertiary deposits which are known to be underlain at no great depth by the Dakota sandstone. In the northeastern part of the county the sandstone is overlain by 100 feet or more of Benton shales. The State well, 6 miles south by east of Ulysses, at a depth of 231 feet reached an excellent water supply that rose to within 123 feet of the surface.[1]

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 299.

William Easton Hutchinson has written a letter describing the water of the county. It appears from his statement that in the west half of the county the depth to water averages about 40 feet, but that in the southern part and south of South Fork of Cimarron River the depth to water is very much greater. In the eastern half of the county, except in the valleys of the streams, the depth ranges from 100 feet in the central part to 200 feet in the extreme eastern part. In the immediate valley of South Fork of Cimarron River the ground water is near the surface. Regardless of depth, the ground water is sufficient and satisfactory for domestic use.

No analyses or assays of the waters of Grant County are available for presentation.

## GRAY COUNTY.

Gray County is mainly in Arkansas Valley[1] but extends southward to the head of Crooked Creek. The entire area is thickly covered by Tertiary and younger formations, but is known to be underlain by the Dakota sandstone, covered by a greater or less thickness of Benton shale, which is exposed southeast of Montezuma. The depth to sandstone is not precisely known, but it is not great in any portion of the county. Apparently some of the deeper wells in the county have reached it, but no satisfactory records have been obtainable. No flowing water is to be expected, unless possibly from the underlying Red Beds, the water from which would probably be too salty for use.

The analyses (Table 33) are tests of well waters in the vicinity of Cimarron. Analyses 4 and 5 are tests of soft calcic alkaline waters from wells in the sand hills. Analyses 3, 8, 9, 10, 11, and 12 are hard calcic alkaline waters, most of which come from deep wells. Analyses 1 and 2 are tests of calcic sodic saline waters. Analysis 6 shows calcic magnesic sodic saline water, and analysis 7 a calcic sodic magnesic water, both of which in boiler use would prove very bad. Assays 1, 2, and 4 are tests of deep well waters and show low bicarbonates and high sulphates. Assay 3 is a test of a shallow well water which is shown to carry somewhat more bicarbonates and very much more sulphates than the deep wells.

[1] Called "Cimarron Valley" (a manifest error) in Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 300, from which this description is abstracted.

TABLE 33.—*Analyses and assays of ground waters from Gray County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| | 1898. | | | | | | | | | | | | | |
| 1 | Dec. 7 | Cimarron, wells, R. R. tank | | Atchison, Topeka & Santa Fe Ry. | | 141 | 36 | 111 | 154 | | 346 | 90 | 98 | 976 |
| 2 | Nov. 10 | Cimarron, well of Wm. Hoover in river bottom. | | do | | 136 | 18 | 80 | 142 | | 314 | 20 | 56 | 767 |
| 3 | do | Cimarron, J. Morrison's well north of city. | | do | | 83 | 24 | 28 | 128 | | 108 | 27 | 60 | 459 |
| 4 | do | Cimarron, J. F. Good's well in sand hills south of city. | | do | | 58 | 8.9 | 30 | 120 | | 27 | 14 | 24 | 281 |
| 5 | do | Cimarron, H. J. Locken's well in sand hills south of city. | | do | | 58 | 8.9 | 30 | 123 | | 27 | 10 | 19 | 276 |
| 6 | Dec. 7 | Cimarron, J. B. Emery's well, 400 feet east and 200 feet south of depot. | 18 | do | | 168 | 79 | 138 | 113 | | 670 | 111 | 175 | 1,455 |
| | 1900. | | | | | | | | | | | | | |
| 7 | Sept. 11 | Cimarron, surface well | | do | | 215 | 34 | 82 | 208 | | 411 | 56 | 55 | 1,060 |
| 8 | do | Cimarron, well | 98 | do | | 66 | 10 | 18 | 101 | | 62 | 10 | 60 | 327 |
| 9 | do | do | 114 | do | | 53 | 8.4 | 27 | 90 | | 58 | 12 | 34 | 282 |
| 10 | Oct. 17 | Cimarron, well No. 2 | 120 | do | | 52 | 9.9 | 32 | 95 | | 64 | 10 | 14 | 260 |
| | 1902. | | | | | | | | | | | | | |
| 11 | May 30 | Cimarron, 2 deep artesian wells | 119, 129 | do | | 82 | 7.4 | 8.7 | 99 | | 68 | 14 | 34 | 312 |
| 12 | Sept. 5 | Cimarron, artesian well | | do | Tr. | 53 | 14 | 25 | 90 | | 73 | 12 | 24 | |
| | | ASSAYS. | | | | | | | | | | | | |
| | 1907. | | | | | | | | | | | | | |
| 1 | Nov. 21 | Cimarron, well of D. Francisco, Avenue A, block 11, lots 11, 12, and 13. | 180 | | 0.0 | | | | .0 | 185 | 55 | 10 | | |
| 2 | do | Cimarron, well of C. M. Weeks, Avenue A and Fifth Street, block 13, lot 6. | 128 | | .0 | | | | .0 | 180 | 62 | 15 | | |
| 3 | do | Cimarron, well in front of Smith's restaurant on Main Street. | 25 | | .5 | | | | .0 | 228 | 313 | 46 | | |
| 4 | do | Cimarron, 2 wells of Atchison, Topeka & Santa Fe Ry. | 100 | | .0 | | | | .0 | 180 | 76 | 20 | | |

## GREELEY COUNTY.

Greeley County, on the high plains of western Kansas, slopes eastward from an altitude of about 4,000 feet above sea level on the State line to 3,500 feet on its eastern margin. The surface is more or less deeply covered by Tertiary deposits, but the Niobrara chalk probably lies at no great depth throughout the area, although possibly near the extreme north margin of the county there may be an overlap of Pierre shale. The dip is gently to the northeast. The Niobrara is probably from 600 to 700 feet thick and is separated from the Dakota sandstone by 400 feet of Benton shales. In the southeastern part of the county this sandstone lies from 800 to 1,100 feet deep, the depth increasing gradually from southeast to northwest until it is about 1,400 feet in the northwest corner of the county. In a well recently bored at Horace, Kans., the Dakota sandstone was reached at a depth of 1,050 feet and was found to have a thickness of 300 feet. Layers of clay were intercalated in the sandstone. The well was continued to 1,350 feet, where the "Red Beds" were found. The water rises within 700 feet of the surface and 40 gallons per minute may be pumped. The record of this well throws a most important light on the position and capabilities of the Dakota sandstone in western Kansas. The thickness of the overlying beds is shown and the head of water ascertained. The low head of water in the Horace well indicates that there are no prospects for flowing water in the higher lands of western Kansas.[1]

The evidence obtained from various wells along the line of the Missouri Pacific Railway shows that there is a great underground ridge in the Cretaceous floor, in many places coming to within 50 or 75 feet of the surface, with little water above the underground ridge. This part of Greeley County is one of the most unfortunate areas in the State in this respect, yet it appears on the map to be completely covered with the Tertiary formations. In places the water is relatively abundant and of good quality. One of the worst features of this condition is that there are practically no indications on the surface where water can be obtained and where it can not. It seems to be almost wholly dependent upon the existence of ravines and channels in the surface of the Cretaceous floor, the existence of not one of them being indicated at the surface. The State well at Tribune, in the valley of the White Woman, reached the Cretaceous floor without passing through any water-bearing sand, while other wells near by on the highest ridges in the county found large quantities of water.

* * * * * * *

In the western portion of Greeley County, where the Niobrara forms an underground ridge, water is very difficult to find in abundance, and often where a well is supplied with even a small quantity, the character of the water is such that it is not very usable because of the mineral substances contained in it. It would seem that the Niobrara floor under this area rises so decidedly that the underflow of sheet water does not find its way over it, and in consequence the Tertiary formation, although being in general of the same character as in other places, does not contain a supply of water. Along the valley of the White Woman, however, there is a supply of water in the sands, gravels, and clays, which seemingly is brought by the drainage of the valley.[2]

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 300-301.

[2] Report of the Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, pp. 101, 112.

In Table 34 the only analysis is of water from the wells of the Missouri Pacific Railway at Tribune. The water is soft. One of the assays is a test of water from the public well in Tribune which is shown to be soft. The assays of the two wells at Horace show that both well waters have high permanent hardness and that the chlorides in the private well are rather high.

TABLE 34.—*Analysis and assays of underground waters from Greeley County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | | | |
| 1 | .......... | Tribune, 3 wells...... | 129 | Missouri Pacific Ry. | 41 | 1.7 | 39 | 5.2 | 5 | 67 | .... | 7.8 | 7.8 | 34 | 209 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Dec. 14 | Horace, public well.. | *a*115 | .................. | ... | .0 | ... | ... | .... | .0 | 176 | 82 | 40 | .... | .... |
| 2 | ....do.... | Horace, well of J. C. Holmes. | 121 | .................. | ... | .0 | ... | ... | .... | .0 | 133 | 168 | 116 | .... | .... |
| 3 | ....do.... | Tribune, public well. | 96 | .................. | ... | .0 | ... | ... | .... | .0 | 188 | Tr. | 15 | .... | .... |

*a* About.

## GREENWOOD COUNTY.

As Greenwood County is underlain by Pennsylvanian rocks, hard waters must necessarily be expected.

The analysis (Table 35) is of a very hard water. Assay 1 is a test of water from the spring which was much used by the pioneers and which gave to the city of Eureka its name. The water is very much harder than that from the city wells, of which assay 2 is a test.

TABLE 35.—*Analysis and assays of underground waters from Greenwood County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | .......... | Madison, well on farm of Arnold Girard,*a* sec. 2, T. 22 S., R. 12 E. | 22 | F. W. Bushong. | 13 | 9.2 | 408 | 384 | 550 | 274 | .... | 3,054 | 70 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. May 14 | Eureka, Eureka Spring........ | .... | .................. | ... | .0 | ... | ... | .... | .0 | 364 | 431 | 421 |
| 2 | ...do..... | Eureka, city supply, 2 wells.. | 21 | .................. | ... | .0 | ... | ... | .... | .0 | 307 | Tr. | 14 |

*a* Quoted from Kansas Acad. of Science, vol. 17, p. 53.

## HAMILTON COUNTY.

Hamilton County, in Arkansas Valley, in the extreme western portion of the State, is underlain by the Dakota sandstone, Benton shales, and Niobrara formation, all of which dip gently to the northeast; the higher lands have a thick cover of Tertiary deposits. The Dakota sandstone is exposed in the southwest corner of the county, and the Benton shales appear in Arkansas Valley and at some isolated points to the south. The northern third of the county is underlain by Niobrara formation, which is exposed in some of the depressions north of Coolidge and Syracuse.

The Dakota sandstone yields water to a number of wells in Arkansas Valley, some of which flow in the eastern margin of the Arkansas Valley artesian area, which extends into the center of this county. At Coolidge there is a group of flowing wells, ranging in depth from 226 to 300 feet, which furnish flows of 27 to over 100 gallons a minute under slight pressure. Farther down the valley, especially near Syracuse, there are a number of wells in which the water rises within 30 feet of the surface. Several wells have been sunk in portions of the county away from Arkansas Valley but have not reached Dakota sandstone. Even at Coolidge, flowing water is obtainable only in the lower part of the valley. The State well, 6 miles due north of Kendall, is 196 feet deep and obtains a water supply at 180 to 192 feet from Tertiary gravel and fine sand lying on Niobrara chalk. A number of wells in various parts of the county obtained supplies from this horizon, which is the principal source, the shales below rarely containing any water.[1]

Analyses 1 and 2 (Table 36) are tests of waters at Coolidge. Analysis 1 indicates a calcic sodic magnesic saline water, and analysis 2 a calcic magnesic saline water. Analyses 3 to 8 show the quality of certain well waters about Kendall. Analysis 3 indicates a soft calcic alkaline water. Analysis 4 shows a calcic sodic saline water. Analyses 5, 6, and 8 are sodic alkaline waters that vary from fair to good for use in boilers. A sodic saline water is shown by analysis 7. The quality of waters around Syracuse is shown by analyses 9 to 20. Hard calcic alkaline waters are indicated by analyses 12 and 14. Calcic saline waters, poor for boiler use, are shown by analyses 15, 16, and 17. A very bad water for steam boilers is the calcic magnesic sodic saline water shown by analysis 13. Sodic alkaline waters are indicated by analyses 9, 10, 11, 19, and 20. A sodic saline water good for boiler use is shown by analysis 18.

The quality of several well waters in Coolidge is shown by assays 1 to 4; these waters are all high in sulphates, but the shallow well water (assay 4) is notably the highest. The character of well waters at Syracuse is indicated by assays 5, 6, and 7. These waters are all high in sulphates, but the shallow well water (assay No. 1) is especially so.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 301.

TABLE 36.—*Analyses and assays of underground waters from Hamilton County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | ........ | Coolidge, artesian well | ........ | Atchison, Topeka & Santa Fe Ry. | ........ | 2.2 | 66 | 27 | 60 | 90 | ........ | 222 | 18 | 12 | ........ |
| 2 | 1902. May 30 | Coolidge, 2 artesian wells | 275, 300 | do | ........ | ........ | 74 | 23 | 33 | 75 | ........ | 171 | 35 | 72 | 483 |
| 3 | 1898. Nov. 25 | Kendall, spring of M. Martlett, near highland, sec. 10, T. 25 S., R. 38 W. | ........ | do | ........ | ........ | 55 | 7.9 | 2.7 | 93 | ........ | 15 | 4 | 31 | 209 |
| 4 | 1900. May 22 | Kendall, well from fine sand | 152 | do | ........ | ........ | 221 | 35 | 60 | 63 | ........ | 432 | 46 | 70 | 928 |
| 5 | June 22 | Kendall, artesian well | 215–368 | do | ........ | ........ | 34 | ........ | 136 | 166 | ........ | 79 | 15 | 36 | 464 |
| 6 | July 6 | do | 349–367 | do | ........ | ........ | 34 | 7.4 | 104 | 106 | ........ | 138 | 15 | 26 | 430 |
| 7 | 1902. Sept. 5 | do | ........ | do | 29 | 8.9 | 24 | 11 | 114 | 96 | ........ | 168 | 12 | ........ | ........ |
| 8 | May 30 | do | 500 | do | ........ | ........ | 34 | 8.4 | 114 | 121 | ........ | 143 | 12 | 55 | 488 |
| 9 | 1898. Nov. 12 | Syracuse, well of rolling mill of H. R. Taylor. | 154 | do | ........ | ........ | 31 | 11 | 69 | 96 | ........ | 91 | 14 | 27 | 344 |
| 10 | Nov. 25 | do | 154 | do | ........ | ........ | 30 | 11 | 68 | 95 | ........ | 88 | 17 | 27 | 339 |
| 11 | Nov. 7 | Syracuse, C. T. Rose's well, 700 feet northeast of depot, water within 22 feet of surface. | 186 | do | ........ | ........ | 33 | 12 | 102 | 113 | ........ | 134 | 17 | 24 | 418 |
| 12 | Dec. 7 | Syracuse, J. H. Bolt's well, 1½ miles south of tracks. | 1,120 | do | ........ | ........ | 63 | 13 | 34 | 89 | ........ | 113 | 17 | 48 | 377 |
| 13 | do | Syracuse, railway tank well | 28 | do | ........ | ........ | 343 | 80 | 110 | 203 | ........ | 962 | 61 | 116 | 1,876 |
| 14 | do | Syracuse, E. Osteton's well, in sand hills 6½ miles south of city. | 15 | do | ........ | ........ | 80 | 29 | 21 | 132 | ........ | 92 | 32 | 48 | 433 |
| 15 | do | Syracuse, I. Overton's well, about 1 mile south of track. | 28 | do | ........ | ........ | 161 | 24 | 109 | 254 | ........ | 291 | 7.3 | 216 | 1,061 |
| 16 | 1899. Feb. 24 | Syracuse, spring of G. W. Dean, SE. ¼ sec. 30, north of city. | ........ | do | ........ | ........ | 120 | 25 | 48 | 150 | ........ | 226 | 17 | 96 | 681 |
| 17 | July 28 | Syracuse, well | 157 | do | ........ | ........ | 120 | 53 | 106 | 79 | ........ | 391 | 68 | 123 | 847 |
| 18 | Oct. 25 | do | 170 | do | ........ | ........ | 63 | 3.9 | 203 | 174 | ........ | 254 | 42 | 135 | 876 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 1902. Apr. 16 | Syracuse, 1 artesian well | 250 | ....do | ...... | ...... | 18 | 4.4 | 153 | 138 | ...... | 143 | 12 | 24 | 493 |
| 20 | 1904. May 4 | Syracuse, springs, 2 miles from city | ...... | ....do | ...... | ...... | 34 | 21 | 57 | 89 | ...... | 112 | 20 | 58 | 409 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Nov. 29 | Coolidge, public well | 307 | ...... | ...... | 1.5 | ...... | ...... | ...... | .0 | 200 | 181 | 20 | ...... | ...... |
| 2 | ...do | Coolidge, Atchison, Topeka & Santa Fe Ry. well.[a] | 312 | ...... | ...... | 1.5 | ...... | ...... | ...... | .0 | 191 | 208 | 15 | ...... | ...... |
| 3 | ...do | Coolidge, schoolhouse well | 145 | ...... | ...... | .0 | ...... | ...... | ...... | .0 | 200 | 150 | 20 | ...... | ...... |
| 4 | ...do | Coolidge, well in front of the Coolidge House. | 30 | ...... | ...... | Tr. | ...... | ...... | ...... | .0 | 204 | (b) | 78 | ...... | ...... |
| 5 | Nov. 28 | Syracuse, well of R. B. Bradley | 14 | ...... | ...... | .0 | ...... | ...... | ...... | .0 | 272 | 574 | 30 | ...... | ...... |
| 6 | ...do | Syracuse, well of rolling mill of H. R. Taylor.[a] | 154 | ...... | ...... | .0 | ...... | ...... | ...... | .0 | 241 | 98 | 15 | ...... | ...... |
| 7 | ...do | Syracuse, well of Atchison, Topeka & Santa Fe Ry. | 287 | ...... | ...... | Tr. | ...... | ...... | ...... | .0 | 272 | 140 | 15 | ...... | ...... |

a From Dakota sandstone.

b $SO_4$ greater than 626.

## HARPER COUNTY.

As Harper County is underlain by Permian rocks, it is probable that deep wells will yield highly mineralized waters.

In Table 37, analyses 1 and 2 are tests of waters in Anthony. A sodic calcic saline water is shown by analysis 1 and a calcic alkaline water by analysis 2. Tests of water at Attica are recorded in analyses 3 and 4; the former indicates a sodic calcic saline water and the latter a calcic sodic alkaline water. The shallow well water at Walden is shown by analysis 5 to belong to the calcic magnesic alkaline class.

The city water of Anthony is shown by assay 1 to carry bicarbonates in moderate amount and high sulphates. The other assays are tests of well waters in Harper. Soft waters are indicated by assays 2 and 3. Assays 4 to 7 indicate waters high in bicarbonates, sulphates, and chlorides; therefore, these waters are so hard as to be distinctly undesirable for domestic and manufacturing use.

TABLE 37.—*Analyses and assays of underground waters from Harper County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1901. May 24 | Anthony, city water, wells | 16–23 | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 58 | 17 | 70 | 86 | ........ | 68 | 108 | 53 | 460 |
| 2 | 1908. Sept. | Anthony, well | 20 | Chicago, Rock Island & Pacific Ry. | ........ | a 5.5 | 53 | 16 | 36 | 112 | ........ | 49 | 28 | ........ | 300 |
| 3 | 1901. July 5 | Attica, surface well | ........ | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 46 | 26 | 60 | 94 | ........ | 80 | 79 | 87 | 472 |
| 4 | 1902. Oct. 21 | .....do | ........ | .....do | 20 | 6.5 | 57 | 24 | 55 | 122 | ........ | 70 | 60 | ........ | ........ |
| | 1908. Sept. | Walden, well 30 feet from Chicago, Rock Island & Pacific Ry. tank. | 22 | Chicago, Rock Island & Pacific Ry. | ........ | a .8 | 50 | 25 | 38 | 97 | ........ | 71 | 54 | ........ | 314 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1908. Jan. 6 | Anthony, city supply, from all of the wells and points at the edge of Bluff Creek. | 16–23 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 232 | 88 | 36 | ........ | ........ |
| 2 | Jan. 5 | Harper, city supply, well | 30 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 240 | Trace. | 26 | ........ | ........ |
| 3 | Jan. 6 | Harper, well of Geo. Mills, block 50, lots 11 and 12, original town sites. | 58 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 178 | 37 | 41 | ........ | ........ |
| 4 | ...do | Harper, well of Mrs. David Brown, block 25, lot 6. | 25 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 454 | 286 | 339 | ........ | ........ |
| 5 | ...do | Harper, well of David Brown, block 40, lot 5. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 508 | 460 | 382 | ........ | ........ |
| 6 | ...do | Harper, well at creamery of Hess & Erb. | 25 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 400 | 460 | 352 | ........ | ........ |
| 7 | ...do | Harper, well of Harper Mill & Elevator Co. [b] | 35 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 386 | ........ | 166 | ........ | ........ |

a $SiO_2+Fe_2O_3+Al_2O_3$.

b $SO_4$ greater than 626.

## HARVEY COUNTY.

Harvey County is underlain by Permian rocks, and as these rocks, as well as those beneath, yield highly mineralized waters, successful deep wells are improbable. The remarkable *Equus* beds (see pp. 34–35), cross the western part of the county and yield the public water supply of Newton.

Analysis 1, Table 38, shows a sodic magnesic saline water; one that as a drinking water would have a decided laxative effect. Analysis 2 denotes a hard calcic saline water. Analyses 3, 4, and 5 are tests of calcic sodic alkaline waters. A calcic magnesic alkaline water is shown by analysis 6.

The assays represent tests of well waters at Halstead and indicate soft waters.

TABLE 38.—*Analyses and assays of underground waters from Harvey County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1904. May 23 | Braddock, spring | ........ | Atchison, Topeka & Santa Fe Ry. | 1.7 | ........ | 22 | 55 | 249 | 58 | ........ | 655 | ........ | 30 | 98 | 1,169 |
| 2 | 1902. Oct. 22 | Burrton, surface well | ........ | ....do | 20 | 0.7 | 53 | 14 | 29 | 72 | ........ | 93 | ........ | 27 | ........ | ........ |
| 3 | Oct. 1 | Halstead, surface well | ........ | ....do | 21 | 1 | 79 | 11 | 78 | 142 | ........ | 135 | ........ | 24 | ........ | ........ |
| 4 | Sept. 19 | Newton, well | ........ | ....do | 23 | ........ | 73 | 9.8 | 61 | 177 | ........ | 33 | ........ | 18 | ........ | ........ |
| 5 | 1906. Nov. 21 | Newton, wells 3, 4, and 5, city waterworks. | 131 | F. W. Bushong | 23 | 1 | 57 | 7.1 | 32 | .0 | 320 | 20 | 1.8 | 13 | ........ | 308 |
| 6 | 1902. Sept. 25 | Sedgwick, well | ........ | Atchison, Topeka & Santa Fe Ry. | 24 | ........ | 93 | 16 | 20 | 174 | ........ | 34 | ........ | 12 | ........ | ........ |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | 1906. Nov. 16 | Halstead, well of Halstead Milling & Elevator Co. | 40 | ........ | ........ | .5 | ........ | ........ | ........ | .0 | 288 | ........ | ........ | 40 | ........ | ........ |
| 2 | ...do..... | ....do | 80 | ........ | ........ | .8 | ........ | ........ | ........ | .0 | 246 | Trace. | ........ | 14 | ........ | ........ |
| 3 | ...do..... | Halstead, well of Dr. E. M. Hoover, Second and Chestnut streets.[a] | 87 | ........ | ........ | .3 | ........ | ........ | ........ | .0 | 241 | ...do... | ........ | 14 | ........ | ........ |
| 4 | ...do..... | Halstead, well of Mr. Shepard, Tenth Street.[b] | 102 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 207 | ...do... | ........ | 14 | ........ | ........ |

[a] Put down in 1897.

[b] Put down in 1884. Water rises within 20 feet of surface.

## HASKELL COUNTY.

Haskell County is situated on the High Plains, between Arkansas and Cimarron Rivers. Its entire surface is mantled by Tertiary deposits from 20 to 100 feet or more in thickness, underlain in greater part by Benton shales. In the southern portion of the county the underlying Dakota sandstone is probably not far below the surface. This sandstone is reached by several wells in which water rises somewhat, but gives no promise of a flow. At Santa Fe a well was bored 1,300 feet or more through Tertiary deposits, Benton shale, Dakota sandstone, and far into the "Red Beds," but no flowing water was obtained.[1]

No complete mineral analyses of waters in this county are available for publication. The assays (Table 39) are typical of the best waters that are drawn from the "underflow" which is moving slowly southeastward over the Cretaceous floor. These waters are soft and satisfactory for domestic use.

TABLE 39.—*Assays of ground waters from Haskell County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | 1907. | | | | | | | |
| 1 | Nov. 4 | Santa Fe, well of J. F. Rutledge, Santa Fe Hotel | 330 | 0.0 | 0.0 | 185 | Trace. | 15 |
| 2 | ...do..... | Santa Fe, well of J. J. Miller, block 36, lot 7, Powell's addition | 382 | Trace. | .0 | 185 | Trace. | 10 |
| 3 | ...do..... | Santa Fe, well of Jas. S. Patrick, NE. ¼ sec. 1, T. 29 S., R. 33 W | 208 | Trace. | .0 | 185 | Trace. | 10 |
| 4 | ...do..... | Santa Fe, well of J. H. Graver, 9 miles southeast of city on SW. ¼ sec. 8, T. 29 S., R. 31 W | 159 | .0 | .0 | 178 | Trace. | 10 |
| 5 | ...do..... | Santa Fe, well of John Rogers, 13 miles southeast of city on NE. ¼ sec. 27, T. 29 S., R. 31 W | 150 | Trace. | .0 | 180 | Trace. | 15 |

## HODGEMAN COUNTY.

The greater part of Hodgeman County is underlain by the Benton shales, but the higher divides are capped by Tertiary deposits, and Pawnee Valley, in the eastern part, cuts into the Dakota sandstone. Some of the numerous wells penetrate Dakota sandstone and obtain satisfactory supplies of water, especially wells in Pawnee Valley below Jetmore. In the extreme northwest corner of the county the Dakota sandstone lies about 400 feet below the surface; in the extreme southwest portion, about 200 to 250 feet; throughout the county, therefore, the sandstone is within reach of wells of moderate depth.[1]

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 303.

From the foregoing paragraph it appears that wells in Hodgeman County may derive their water from the Tertiary deposits, the Benton group, or the Dakota sandstone. Water from the first and last of these is generally very satisfactory, though that drawn from the upper part of the Dakota sandstone is apt to carry enough sulphates to make it desirable to sink the wells below the gypsiferous shales of the formation. The water that is derived from the Benton group is usually limited in quantity and highly mineralized. George I. Adams has called attention to the fact that in this county a fluviatile deposit, consisting of Tertiary sands and gravels and worked-over clay is found in every small stream and draw.[1] At Jetmore in the bottoms of Buckner Creek wells at the depth of 32 feet discover water in this material, which largely disappears farther upstream at the limits of the Benton group.

The only complete analysis (Table 40) is that of water from a shallow well in the alluvium; it indicates a calcic alkaline water of considerable temporary hardness. Assay 4 shows the composition of water from a well that is probably in the alluvium. Assay 1 is high in sulphates and is a test of water from a well that probably draws its water from the Benton group. Assays 2 and 3 indicate soft waters from wells that are in the Tertiary and tap the "sheet water" or "underflow." Assays 5, 6, and 7 show the quality of waters drawn from the Dakota sandstone.

TABLE 40.—*Analysis and assays of ground waters from Hodgeman County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1902. | ANALYSIS. | | | | | | | | | | | |
| 1 | Oct. 15 | Jetmore, surface well.. | ... | Atchison, Topeka & Santa Fe Ry. | 54 | 1.5 | 95 | 14 | 31 | 170 | .... | 36 | 24 |

[1] Report of the Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, pp. 105 et seq.

TABLE 40.—*Analysis and assays of ground waters from Hodgeman County*—Continued.

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1907. Dec. 6 | Jetmore, well of Geo. E. Martin, NE. ¼ sec. 35, T. 22 S., R. 24 W. | 15 | 0.0 | 0.0 | 272 | 116 | 10 |
| 2 | ...do.... | Jetmore, well at almshouse, NE. ¼ sec. 6, T. 24 S., R. 23 W. | 60± | Tr. | .0 | 222 | Tr. | 34 |
| 3 | ...do.... | Jetmore, J. McClure's well, NE. ¼ sec. 12, T. 24 S., R. 24 W. | 63 | .0 | .0 | 233 | Tr. | 15 |
| 4 | ...do.... | Jetmore, public well | 70 | 1.0 | .0 | 241 | Tr. | 10 |
| 5 | ...do.... | Jetmore, well of T. J. Palmer | 200± | .0 | .0 | 278 | 47 | 24 |
| 6 | ...do.... | Jetmore, well of Geo. Orbison, SW. ¼ sec. 36, T. 22 S., R. 24 W. | 240 | .0 | .0 | 254 | 181 | 55 |
| 7 | ...do.... | Jetmore, well of C. W. Patchen, SW. ¼ sec. 6, T. 24 S., R. 23 W. | 256 | Tr. | .0 | 338 | 173 | 40 |

## JACKSON COUNTY.

As Jackson County is underlain by Pennsylvanian rocks hard waters must be expected, except possibly from some shallow wells that are sunk in glacial deposits.

The analysis (Table 41) shows a calcic sodic alkaline water. Assay 1 indicates a soft water and assay 2 one of decided temporary and permanent hardness.

TABLE 41.—*Analysis and assays of ground waters from Jackson County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1902. Dec. 10 | Holton, well of Chicago, Rock Island & Pacific Ry. | ... | Kennicott Water Softener Co. | 33 | 1.4 | 120 | 27 | 86 | 209 | .... | 125 | 76 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. July 15 | Holton, well of city hotel | 60 | | ... | .0 | ... | ... | .... | .0 | 258 | Tr. | 65 |
| 2 | ...do.... | Holton, well of Perkins Ice and Cold Storage Co. | 72 | | ... | 1.5 | ... | ... | .... | .0 | 340 | 47 | 100 |

## JEFFERSON COUNTY.

Underground water is obtained in Jefferson County under practically the same conditions as in Jackson County.

The analysis, Table 42, shows a calcic magnesic alkaline water. Assay 1 indicates a hard water and assay 2 shows the highly mineralized water that may be expected in deep wells.

TABLE 42.—*Analysis and assays of ground waters from Jefferson County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1903. Feb. 24 | Medina, surface well | ...... | Kennicott Water Softener Co. | 20 | ... | 65 | 24 | 3.9 | 135 | .... | 34 | 6 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. July 13 | Valley Falls, well of J. M. Piazzek.[a] | 25 | .................. | ... | 0.0 | ... | ... | .... | .0 | 246 | 127 | 162 |
| 2 | ...do..... | Valley Falls, well of Mel. Legler.[b] | 1,253 | .................. | ... | 3.5 | ... | ... | .... | .0 | 116 | .... | 36,800 |

[a] Located between the Leavenworth, Kansas & Western and Missouri Pacific Ry. tracks.
[b] Prospect hole put down in 1889. Water comes in at 400 feet. $SO_4$ greater than 626.

## JEWELL COUNTY.

Jewell County is situated on the high divide between Solomon and Republican rivers. The high ridges in the northwestern part of the county are capped by Tertiary grit; the central, northern, and western portions are underlain by Niobrara chalk; and, in the lower lands to the south and east the Benton shales reach the surface. The Dakota sandstone, which outcrops in Republican and Solomon valleys, underlies the entire county, lying nearly level or dipping gently to the northwest. In the eastern and southern sections of the county it lies but a short distance below the surface, but the depth increases gradually under the higher lands to the north and west, so that probably it lies 700 to 800 feet deep in the northwest portion of the county. Apparently the main body of the sandstone has not been reached by deep wells in this county, although several borings 300 to 500 feet deep have been sunk through the Benton shales to a water-bearing horizon, which in this region contains considerable salt and has yielded salty waters which have not been useful. One well near Jewell, 337 feet deep, obtained salt water which rose within 25 feet of the surface. At Ionia is a similar well 432 feet deep. At Mankato a well 500 feet deep found an abundance of salt water which rose within 50 feet of the surface. Borings 3½ miles northwest of Lovewell 380 and 400 feet deep also found salt water. Unfortunately these borings were not made sufficiently deep to test Dakota sandstone, for although it is not likely that wells in that formation would obtain flowing water, except possibly on the lowest lands, the water may be expected to be of good quality.[1]

It will be seen by referring to the geologic map that a long narrow tongue of the Tertiary formation extends along the north side of the county to the Republican River, occupying the high ridge between the Republican River on the north and the White Rock on the south. The Cretaceous chalk beds are exposed along the White Rock almost entirely across the county, and also along the bluffs of the Republican, but on this divide the whole of the formation to a depth of about 100 feet is Tertiary. A cross section of the Tertiary ridge taken from surface contours and the records of various wells shows that the Tertiary ridge rests in an old Cretaceous trough. The whole belt is full of wells, usually nearly 100 feet deep, every one of which furnishes a large supply of good water, while along the Republican brakes to the north, or the White Rock to the south, water is hard to obtain by digging, and that which is procured is so mineralized it is not very serviceable. Another evidence favoring the idea of a Cretaceous trough under the Tertiary ridge is the condition of springs. Scarcely a spring is known along either side of the belt throughout Jewell County, but at the eastern end of the area, along the bluffs of the Republican River, springs are numerous. The supply of water they furnish is abundant and the quality is the same as that produced by the wells of the Tertiary area.[2]

The analyses and assays (Table 43) that are available for publication are entirely inadequate to show the different kinds of ground waters in the county, for no tests have been made of waters from wells in the Tertiary nor of the salt water from the deep wells. Analysis 1 shows a very heavily mineralized magnesic calcic saline water. Analysis 4 is a test of a magnesic calcic potassic saline water that, as a drinking water, would be highly laxative. Analysis 2 indicates a hard calcic alkaline water. Analysis 3 shows a sodic calcic alkaline water. The two assays indicate hard unsatisfactory waters. These analyses as a whole show that the waters outside of the Tertiary area are unsatisfactory for domestic and industrial use. This accords with the popular idea that it is difficult to find any other than hard waters in Jewell County. Outside of the Tertiary area the only solution of the water problem appears to be to sink wells deep into the Dakota sandstone.

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 304–305.

[2] Report of the Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 97.

TABLE 43.—*Analyses and assays of ground waters from Jewell County.*

[Parts per million.]

| No. | Date. | Source. | Depth. (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | ........ | Burr Oak, well | ........ | G. H. Failyer and E. C. M. Breese.[a] | 88 | [b] 10 | 462 | 375 | [c] 32 | 25 | ........ | 2,941 | 106 | ........ | ........ |
| 2 | ........ | Mankato, city waterworks well | 30 | Missouri Pacific Ry. | 33 | 4.2 | 132 | 12 | 59 | 193 | ........ | 124 | 41 | 43 | 644 |
| 3 | ........ | Montrose, well 500 feet from tank of Chicago, Rock Island & Pacific Ry. | 22 | Chicago, Rock Island & Pacific Ry. | ........ | [d] 32 | 75 | 12 | 175 | 257 | ........ | 121 | 44 | ........ | 715 |
| 4 | ........ | Omio, spring near[e] | ........ | G. H. Failyer and J. T. Willard.[f] | 86 | [g] Trace. | 475 | 714 | [h] 469 | ........ | ........ | 5,064 | 149 | ........ | ........ |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Sept. 26 | Burr Oak, well of J. Crimmins. | ........ | ........ | ........ | 0.0 | ........ | ........ | ........ | .0 | 300 | 383 | 41 | ........ | ........ |
| 2 | Feb. 23 | Mankato, city waterworks well | 30 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 370 | 116 | 45 | ........ | ........ |

[a] Kansas Univ. Geol. Survey, vol. 7.
[b] Aluminum (Al), 0.62.
[c] Lithium (Li), 0.8.
[d] $SiO_2+Fe_2O_3+Al_2O_3$.
[e] Probably from near the Niobrara formation.
[f] Rept. Board of Irrigation Survey and Experiment to the Legislature of Kansas, 1895-96, p. 75.
[g] Al, 102.
[h] K, 283; Na, 186.

## JOHNSON COUNTY.

Ground water is obtained under the same conditions in Johnson County as in Jackson County, except that there are probably no wells in the drift, as this county appears to lie outside the glaciated area. Shallow springs and wells yielding hard waters are common. No analyses are presented. The only assays (Table 44) were made in Olathe and indicate hard waters.

TABLE 44.—*Assays of underground waters from Johnson County.*

[Parts per million.]

| No. | Date. | Source. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|
| | 1907. | | | | | | |
| 1 | Jan. 5 | Olathe, well of State School for the Deaf | 0.0 | 0.0 | 183 | 116 | 24 |
| 2 | ...do..... | Olathe, well of E. P. Mills | .0 | .0 | 410 | 103 | 70 |

## KEARNY COUNTY.

Kearny County is in Arkansas Valley, and its geologic relations are similar to those in Hamilton County, but the formations are for the most part obscured by a heavy covering of Tertiary and alluvial deposits. The Dakota sandstone lies at a depth of about 300 feet along Arkansas Valley, and is deeper in the northern portion of the county, owing to the northeasterly dip of the beds and the rise of the land. No deep wells are reported, but abundant water supplies are obtainable from the Dakota sandstone at moderate depths in Arkansas Valley, though flows are not probable. The underlying "Red Beds" may yield flowing water, which would, however, doubtless be too salty for use.[1]

Analyses 1 to 6 (Table 45) show calcic sodic magnesic saline waters that for use in boilers run from poor to bad. Analysis 7 indicates a calcic sodic saline water that is very good in steam boilers. Analyses 8 and 11 are tests of calcic magnesic saline waters that are very bad for steam boilers. Analyses 9 and 10 show calcic alkaline waters suitable for boiler use. Assays 1, 2, 4, 6, 7, and 9 indicate waters high in sulphates, but which carry only moderate amounts of bicarbonates. The water of which assay 4 is a test is high in chlorides. Assay 3 shows a soft deep well water. Assay 5 indicates that the water of a widely known well in the sand hills is soft. Assay 8 shows a water moderately mineralized by bicarbonates and which carries rather high sulphates.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 305.

TABLE 45.—*Analyses and assays of underground waters from Kearny County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1907. Dec. 2 | Deerfield, deep-water well No. 1 of United States Reclamation Service. | 198 | Archie J. Weith [a] | 31 | 0.14 | 82 | 38 | 90 | 0.0 | 250 | 199 | 4 | 42 | ........ | 591 |
| 2 | 1898. Nov. 30 | Lakin, A. R. Beattye's well | ...... | Atchison, Topeka & Santa Fe Ry. | ........ | ...... | 146 | 36 | 70 | 130 | ........ | 310 | ........ | 91 | 123 | ........ |
| 3 | ...do..... | Lakin, Thomas Gibbons's well | ...... | ...do | ........ | ...... | 133 | 25 | 80 | 127 | ........ | 332 | ........ | 37 | 79 | 813 |
| 4 | ...do..... | Lakin, G. G. Bahutge's well | ...... | ...do | ........ | ...... | 110 | 19 | 65 | 96 | ........ | 278 | ........ | 30 | 72 | 669 |
| 5 | ...do..... | Lakin, No. 2, Bantgo's well | ...... | ...do | ........ | ...... | 124 | 25 | 55 | 97 | ........ | 304 | ........ | 36 | 55 | 698 |
| 6 | 1899. Jan. 9 | Lakin, spring one-half mile east of depot. | ...... | ...do | ........ | ...... | 145 | 51 | 147 | 172 | ........ | 476 | ........ | 78 | 108 | 1,176 |
| 7 | 1900. Mar. 12 | Lakin, artesian well | 160 | ...do | ........ | ...... | 50 | 8.4 | 38 | 101 | ........ | 45 | ........ | 20 | 60 | 322 |
| 8 | 1901. July 12 | Lakin, surface well | ...... | ...do | ........ | ...... | 212 | 39 | 47 | 120 | ........ | 460 | ........ | 79 | 91 | 1,048 |
| 9 | 1902. Sept. 5 | Lakin, artesian well | ...... | ...do | 5.6 | 1.8 | 45 | 13 | 28 | 106 | ........ | 35 | ........ | 9.1 | ........ | ........ |
| 10 | May 30 | Lakin, 3 artesian wells | 184, 192, 195 | ...do | ........ | ...... | 53 | 14 | 20 | 102 | ........ | 25 | ........ | 5.2 | 22 | 141 |
| 11 | ...do..... | Lakin, surface well | ...... | ...do | ........ | ...... | 208 | 39 | 51 | 125 | ........ | 453 | ........ | 78 | 96 | 1,039 |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | 1907. Nov. 23 | Deerfield, station 20, well No. 1, United States Reclamation Service. | 50 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 176 | 168 | ........ | 26 | ........ | ........ |
| 2 | ...do..... | Deerfield, station 2, well No. 9, United States Reclamation Service. | 34 | ........ | ........ | .0 | ...... | ...... | ........ | .0 | 222 | 362 | ........ | 46 | ........ | ........ |

[a] Analysis made at the laboratories of the University of Kansas.

TABLE 45.—*Analyses and assays of underground waters from Kearny County*—Continued.

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$) | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ASSAYS—continued. | | | | | | | | | | | | | | |
| 3 | 1907. Nov. 27 | Lakin, Atchison, Topeka & Santa Fe Ry. well. | 186 | ........ | ........ | 0.0 | ........ | ........ | ........ | 0.0 | 191 | Trace. | ........ | 10 | ........ | ........ |
| 4 | ...do..... | Lakin, well at Chas. A. Snyder's livery barn.. | 10 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 267 | (a) | ........ | 151 | ........ | ........ |
| 5 | ...do..... | SE. ½ sec. 16, T. 26 S., R. 37 W., "Sunk Well" at southern edge of the "sand hills." | ........ | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 258 | .0 | ........ | 15 | ........ | ........ |
| 6 | ...do..... | Sec. 32, T. 26 S., R. 37 W., well of Batterton, basin of Bear Creek. | 35 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 254 | 132 | ........ | 30 | ........ | ........ |
| 7 | ...do..... | Sec. 32, T. 26 S., R. 37 W., well of Batterton at the house and above the basin of Bear Creek. | 140 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 191 | 215 | ........ | 30 | ........ | ........ |
| 8 | ...do..... | Sec. 20, T. 26 S., R. 37 W., well of Waechter Bros. in a draw of basin of Bear Creek. | 75 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 211 | 46 | ........ | 20 | ........ | ........ |
| 9 | ...do..... | Sec. 20, T. 26 S., R. 37 W., well of Waechter Bros. in Bear Creek Valley. | 120 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 227 | 86 | ........ | 46 | ........ | ........ |

a $SO_4$ greater than 626.

## KINGMAN COUNTY.

As Kingman County is underlain by Permian rocks the prospect for good waters is poor, for the rocks of this series and of the Pennsylvanian beneath it usually yield highly mineralized waters. But the western part of the county is underlain by Tertiary deposits which normally supply good water.

Analysis 1, Table 46, shows a calcic saline water and analysis 4 a calcic alkaline water; both of these waters have considerable permanent hardness. Analyses 2 and 3 show soft calcic alkaline waters.

Assay 2, Table 46, is a test of the same water as analysis 3, and this water is practically the same as that of which assay 1 is a test and which comes from a spring near the Hinds Spring. Assay 3 shows the composition of the old public water supply of Kingman. The water is apparently affected by the old salt well that is in the city. Assay No. 5 shows rather high chlorides, and it may be that the well from which the water was taken is very slightly influenced by the salt well. The other assays are of reasonably soft waters from shallow wells in the city.

TABLE 46.—*Analyses and assays of underground waters from Kingman County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | .......... | Belmont, well | 12 | Missouri Pacific Ry | 23 | 2.1 | 30 | 8.4 | 5.8 | 32 | ........ | 56 | 8.3 | 24 | 192 |
| 2 | 1902. Oct. 21 | Cunningham, surface well | ........ | Atchison, Topeka & Santa Fe Ry. | 22 | 1.2 | 59 | 6.2 | 6.5 | 100 | ........ | 5.4 | 10 | ........ | ........ |
| 3 | 1904. Aug. 4 | Kingman, springs west of city—new city waterworks. | ........ | Kennicott Water Softener Co. | 22 | 1.3 | 42 | 7 | 12 | 73 | ........ | 13 | 18 | ........ | ........ |
| 4 | 1901. May 24 | Rago, pond fed by spring | ........ | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 57 | 16 | 22 | 79 | ........ | 76 | 32 | 39 | 322 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Dec. 30 | Kingman, Harris Spring (fish pond). | ........ | ........ | ........ | .0 | ........ | ........ | ........ | 12 | 137 | Trace. | 16 | ........ | ........ |
| 2 | ...do..... | Kingman, Hinds Spring (new city supply). | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 127 | Trace. | 16 | ........ | ........ |
| 3 | ...do..... | Kingman, old city supply from 12 wells. | 35–45 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 219 | ........ | 1,378 | ........ | ........ |
| 4 | Dec. 31 | Kingman, well of Kingman Milling Co. | 20 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 186 | 37 | 151 | ........ | ........ |
| 5 | ...do..... | Kingman, well of Pratt Lumber Co., B Street East. | 13 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 173 | Trace. | 26 | ........ | ........ |
| 6 | ...do..... | Kingman, well of Mr. Salman, Avenue B West. | 30 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 160 | Trace. | 20 | ........ | ........ |

## KIOWA COUNTY.

Kiowa County extends from Arkansas Valley southeastward across the divide to Medicine Lodge River. Its surface is covered with younger formations—alluvium and sand hills in the northwest corner and Tertiary deposits on the higher lands to the south and east. The Dakota sandstone lies at no great distance beneath the surface and is exposed on the opposite side of Arkansas River and in the southeast corner of the county. The Dakota thins rapidly to the southeast, owing mainly to the erosion of its surface, and in Medicine Lodge Valley the underlying lower Cretaceous sandstones and "Red Beds" are exposed.

Most of the wells in the county obtain water from the basal portion of the Tertiary deposits, but some have been bored into the underlying Dakota sandstone. One well, 9 miles southwest of Greensburg, has a depth of 202 feet and the water supply rises to 112 feet. Flowing waters are not obtainable in this county, not even from the "Red Beds," which underlie the Dakota and lower Cretaceous sandstones. Possibly the "Red Beds" contain water, but it would be too salty for use.[1]

Analyses 1, 3, and 4 (Table 47) exhibit soft calcic alkaline waters and analysis 2 shows a sodic calcic alkaline water. The two assays indicate water of moderate temporary and low permanent hardness.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 305.

TABLE 47.—*Analyses and assays of underground waters from Kiowa County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | 1902. Dec. 8 | Greensburg, well | | Chicago, Rock Island & Pacific Ry. | 24 | 1.2 | 56 | 7.2 | 17 | 102 | | 10 | 19 | |
| 2 | 1908. Sept. | do | 65 | do | | *a* 13 | 64 | 12 | 78 | 116 | | 26 | 112 | 421 |
| 3 | 1902. Dec. 8 | Wellsford, well | | do | 22 | 1.9 | 39 | 4.1 | 13 | 68 | | 8.2 | 15 | |
| 4 | 1908. Sept. | do | 100 | do | | *a* 11 | 44 | 8.3 | 9.8 | 77 | | 14 | 15 | 180 |
| | | ASSAYS. | | | | | | | | | | | | |
| 1 | 1907. Nov. 6 | Greensburg, well of Jas. I. Parcel | 97 | | | .0 | | | | .0 | 227 | Trace. | 20 | |
| 2 | do | Greensburg, well of Queen City Hotel. | 100 | Chicago. Rock Island & Pacific Ry. | | .0 | | | | .0 | 222 | Trace. | 15 | |

*a* $SiO_2+Fe_2O_3+Al_2O_3$.

## LABETTE COUNTY.

Labette County is underlain by Pennsylvanian rocks, from which, as a rule, hard waters are derived.

No analyses are available for publication. Assay 1, Table 48, shows a water which carries a moderate amount of chlorides and bicarbonates, but which is high in sulphates. Assays 2 and 10 indicate soft waters low in chlorides. Assay 7 is a test of a water low in chlorides and sulphates, but having great temporary hardness. Assay 3 represents the hardest and most unsatisfactory water that was tested in the county, for its permanent and temporary hardness are very great and the chlorides are high. Assays 4 and 5 are tests of flowing wells that are believed to derive their waters from the Ozark dome; these waters have high temporary hardness and chlorides. Assays 6, 8, and 9 show rather unsatisfactory waters, such as are commonly found in the shallow wells in the Pennsylvanian rocks.

TABLE 48.—*Assays of underground waters from Labette County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | | | |
| 1 | July 17 | Bartlett, well | 12 | E. Bartow | 0.0 | 0.0 | 216 | 176 | 45 |
| 2 | ...do... | Bartlett, spring 2½ miles south of city. | | ...do... | .0 | .0 | 255 | Trace. | 9.2 |
| 3 | ...do... | Chetopa, well west of Missouri, Kansas & Texas Ry. depot. | 10–12 | ...do... | Tr. | .0 | 372 | (a) | 142 |
| 4 | ...do... | Chetopa, flowing well 4 miles east and 1 mile north of city.[b] | 950 | ...do... | .0 | .0 | 358 | 44 | 260 |
| | 1906. | | | | | | | | |
| 5 | Dec. 12 | Chetopa, flowing well, city supply.[b] | 1,114 | | .0 | Trace. | 456 | 0.0 | 211 |
| | 1905. | | | | | | | | |
| 6 | July 17 | Oswego, well 1 mile south and 3 miles west of city. | | | .0 | .0 | 264 | 138 | 73 |
| 7 | ...do... | Oswego, well 4 miles south and 5 miles west of city. | 23 | | .5 | .0 | 449 | Trace. | 9.2 |
| 8 | July 19 | Parsons, well 2 miles south of city on upland. | 30 | E. Bartow | .0 | .0 | 293 | 40 | 299 |
| 9 | ...do... | Parsons, well 2 miles south and 2 miles east of city. | 30 | ...do... | .0 | .0 | 274 | 48 | 81 |
| 10 | ...do... | Parsons, well 3 miles south of city. | 20 | ...do... | .0 | .0 | 196 | Trace. | 14 |

[a] $SO_4$ greater than 626. [b] $H_2S$ present.

## LANE COUNTY.

Lane County is mantled by Tertiary deposits resting on several hundred feet of Niobrara chalk, which is exposed in some of the deeper depressions to the north and east. The Dakota sandstone lies at a depth which increases gradually from about 500 feet in the southeastern corner of the county to 700 feet in the northwestern corner, the beds dipping very gently to the north and the surface rising very gradually to the west. A well 400 feet deep 3 miles north of Shields obtains a very small supply of water from a thin sandstone bed, probably in the upper part of the Benton formation. This county lies too high for an artesian flow, but the Dakota sandstone may be expected to yield water that would rise within 300 or 400 feet of the surface and yield an abundant supply to pump wells.[1]

Both the analyses and the assays (Table 49) indicate fairly satisfactory waters from the Tertiary deposits.

TABLE 49.—*Analyses and assays of ground waters from Lane County.*

[Parts per million.]

| No | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | .......... | Healy, 2 wells........ | 110 | Missouri Pacific Ry. | 65 | 1.8 | 58 | 20 | 25 | 118 | .... | 63 | 17 | 12 | 381 |
| 2 | .......... | Pendennis, well..... | 105 | .....do............ | 38 | 1 | 51 | 14 | 8.9 | 112 | .... | 20 | 5.9 | 8 | 260 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Dec. 11 | Dighton, well of Commercial Hotel on Main Street. | ... | .................. | ... | .0 | ... | ... | .... | .0 | 254 | 46 | 75 | .... | .... |
| 2 | ...do.... | Dighton, well of Henry Seemann. | ... | .................. | ... | Tr. | ... | ... | .... | .0 | 254 | Tr. | 4.5 | .... | .... |

## LEAVENWORTH COUNTY.

Leavenworth County is underlain by Pennsylvanian rocks, which yield highly mineralized waters, but there may be wells in glacial deposits that supply water of superior quality.

Analysis 1, Table 50, represents a test of a highly mineralized mine water. The other analysis and the two assays indicate very hard waters.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 306.

TABLE 50.—*Analyses and assays of underground waters from Leavenworth County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | .......... | Leavenworth, natatorium of Home-Riverside Coal-Mining Co., from mines 750 feet deep.[a] | ... | O. F. Stafford.... | 43 | 8.4 | 541 | 232 | 9,296 | .... | .... | 36 | 15,717 |
| 2 | .......... | Leavenworth, water in No. 1 plant of the Home mine.[a] | 60 | .....do............ | 22 | 1.4 | 211 | 110 | 145 | .... | .... | 833 | 132 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. July 12 | Leavenworth, well of Leavenworth Packing Co., 744 Shawnee Street. | 65 | .................. | ... | .0 | ... | ... | ..... | 0.0 | 242 | 492 | 141 |
| 2 | ...do.... | Leavenworth, well of F. E. Lambert, 211 Kiowa Street. | 8 | .................. | ... | .0 | ... | ... | ..... | .0 | 150 | 256 | 130 |

[a] Kansas Univ. Geol. Survey, vol. 7.

## LINCOLN COUNTY.

Lincoln County includes a portion of the valley of Saline River and the adjoining slopes. In the river valley and along the east side of the county the Dakota sandstone is exposed and the higher lands are capped by a few hundred feet of Benton shales. Most of the many wells obtain their water from the Dakota sandstone, some of them from a depth as great as 280 feet. The water rises nearly to the surface and has considerable volume.[1]

The analysis and assays, Table 51, show hard, unsatisfactory waters. Probably wells sunk deep into the Dakota sandstone would yield better water.

TABLE 51.—*Analysis and assays of underground waters of Lincoln County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1902. Sept. 19 | Barnard, well............ | ... | Atchison, Topeka & Santa Fe Ry. | 30 | Tr. | 201 | 17 | 51 | 1.88 | .... | 308 | 36 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. Sept. 9 | Lincoln, city supply, 2 wells. | 43 | ...................... | ... | 0.0 | ... | ... | .... | .0 | 312 | 143 | 39 |
| 2 | Sept. 10 | Lincoln, well of Cooper Ice Co. | 75 | ...................... | ... | .0 | ... | ... | .... | .0 | 356 | 72 | 44 |

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 306.

## LINN COUNTY.

Linn County is underlain by Pennsylvanian rocks and its well waters are hard.

No water analyses are available for publication. Of the assays in Table 52, only 7 and 9 indicate soft waters. Assays 1, 3, and 6 show waters of high temporary and low permanent hardness. Assays 2, 4, and 8 are tests of waters of high temporary and permanent hardness. Assays 10 and 11 show the highly mineralized ground waters that are found at Pleasanton.

TABLE 52.—*Assays of underground waters of Linn County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | | | |
| 1 | June 26 | Boicourt, well 3 miles west and 1 mile north of city.[a] | 78 | E. Bartow | 0.0 | 0.0 | 503 | Trace. | 198 |
| 2 | do | Boicourt, well at Sugar Creek Bridge, southwest of city. | | do | .0 | .0 | 450 | 54 | 20 |
| 3 | June 25 | Lacygne, public well | 30 | do | .0 | .0 | 487 | Trace. | 40 |
| 4 | do | Lacygne, well on high ground 2½ miles north and 4½ miles west of city. | 12 | do | .0 | .0 | 329 | 74 | 56 |
| 5 | do | Lacygne, spring 3 miles east of city.[b] | 11 | do | .0 | .0 | 265 | 43 | 9.7 |
| 6 | do | Lacygne, spring 3½ miles east and 1 mile north of city.[c] | | do | .0 | .0 | 293 | Trace. | 9.7 |
| 7 | do | Lacygne, Rock Spring, 3½ miles east and 2 miles north of city.[c] | | do | .0 | .0 | 265 | Trace. | 9.7 |
| 8 | do | Lacygne, well 6 miles east of city. | | do | .0 | .0 | 341 | 97 | 209 |
| 9 | June 26 | Pleasanton, spring near Mine Creek east of city. | | do | .0 | .0 | 136 | Trace. | 12 |
| | 1907. | | | | | | | | |
| 10 | Aug. 23 | Pleasanton, stock well on Eighth Street. | 25 | do | .0 | .0 | 369 | ([d]) | 290 |
| 11 | do | Pleasanton, Everett's well, Ninth and Main Streets.[e] | 15 | | .0 | .0 | 624 | 573 | 205 |

[a] Odor of $H_2S$.
[b] Used to supply F. W. Pollman's ranch.
[c] Upland.
[d] $SO_4$ greater than 626.
[e] Sunk 30 years ago and believed to be typical of local wells.

## LOGAN COUNTY.

Logan County includes a portion of Smoky Hill Valley and adjoining high plains. The Tertiary deposits have been extensively removed by the river, which has cut a wide valley into the underlying Pierre formation to the west and into the Niobrara chalk to the east. The western and northern parts of the county are underlain by the Pierre shale and the southeastern part by the Niobrara formation. The Dakota sandstone lies at a depth of 800 to 1,000 feet in the southeastern part of the county and 1,000 to 1,500 feet in the higher lands in the northern and western parts, the beds dipping gently to the north. It is probable that the head of water in the Dakota sandstone is sufficient to raise it to an elevation of about 3,000 feet, so that the formation should be expected to yield a flow in wells in the valleys of Smoky Hill River and Twin Butte Creek. Several attempts have been made to reach the deeper-seated waters in this county. The boring put down by the Union Pacific Railroad Co. at Winona is 1,356 feet deep, all below 160 feet being in shales, and is reported as a dry hole. White shale was penetrated from 1,100 to 1,175 feet, probably representing a portion of the Niobrara formation. This hole undoubtedly would have reached the Dakota sandstone within a short distance and found a water supply which would have risen to within 300 or 400 feet below the surface. Two deep borings on Hell Creek, in the extreme southeastern corner of the county, reached a depth of 500 feet, all in the Niobrara formation and the top shales of the Benton, without obtaining water, and a 408-foot boring at Elkader had a similar result. A boring at Oakley is said to have reached a depth of 700 feet and obtained a small amount of water, which rose to within 30 feet of the surface. It is reported that some water was found at 90 feet and at intervals down to 350 feet in alternating sands and clays in part of the Tertiary deposits. The underlying shales extend to the bottom, which lacks about 450 feet of reaching the Dakota sandstone. Oakley is slightly too high for a flow.[1]

The only analysis in Table 53 shows a rather hard calcic magnesic alkaline water at Oakley; assays 1 and 2, which are also tests of well waters in Oakley, show soft waters. Assay 5 indicates low bicarbonates and moderately high sulphates in a well at Winona. The Oakley and Winona waters are derived from the Tertiary deposits. Assays 3 and 4 show very hard waters at Russell Springs.

TABLE 53.—*Analysis and assays of underground waters from Logan County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | | | |
| 1 | 1908. Mar. 18 | Oakley, well | 111 | Union Pacific R. R. | 34 | 0.8 | 70 | 23 | 18 | 129 | .... | 54 | 0.7 | 21 | 350 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Sept. 22 | Oakley, well of V. Kagger, Central Avenue and Fifth Street. | 123 | ........ | ... | .0 | ... | ... | .... | .0 | 232 | T. | .... | 10 | .... |
| 2 | ...do.... | Oakley, well of Union Pacific R. R. | 143 | ........ | ... | .0 | ... | ... | .... | .0 | 222 | T. | .... | 15 | .... |
| 3 | Nov. 24 | Russell Springs, spring at head of draw in south part of city, public supply. | .... | ........ | ... | .0 | ... | ... | .... | .0 | 195 | 287 | .... | 52 | .... |
| 4 | Sept. 23 | Russell Springs, well of R. J. Abell, in bottoms of Smoky Hill River. | 20 | ........ | ... | .0 | ... | ... | .... | .0 | 300 | 626 | .... | 83 | .... |
| 5 | ...do.... | Winona, well of F. E. Brook. | 145 | ........ | ... | .0 | ... | ... | .... | .0 | 229 | 49 | .... | 26 | .... |

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 306–307.

## LYON COUNTY.

Lyon County is underlain by Pennsylvanian rocks, which yield hard waters.

The analysis, Table 54, indicates a sodic calcic saline water. All of the assays, except No. 4, show waters of high permanent hardness; assay 4 indicates a soft water.

TABLE 54.—*Analysis and assays of underground waters from Lyon County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1901. Oct. 3 | Emporia, well at stockyards. | ... | Atchison, Topeka & Santa Fe Ry. | ... | 95 | 12 | 130 | 198 | .... | 75 | 114 | 31 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1905. July 29 | Emporia, well in eastern part of city.[a] | ... | E. Bartow | 0.0 | ... | ... | .... | .0 | 306 | 76 | 229 | .... |
| 2 | June 16 | Reading, well one-fourth mile north of Duck Creek.[b] | ... | ...do | 1.2 | ... | ... | .... | .0 | 287 | 121 | 24 | .... |
| 3 | ...do | Reading, well east of city | ... | ...do | .0 | ... | ... | .... | .0 | 142 | 383 | 35 | .... |
| 4 | ...do | Reading, well near 142-mile Creek. | 35 | ...do | 2.5 | ... | ... | .... | 21 | 215 | T. | 40 | .... |

[a] Peddled in city. [b] On high ground.

## M'PHERSON COUNTY.

About 55 per cent of McPherson County is covered by the *Equus* beds, which occupy what is believed to be an old river channel that connected Arkansas and Smoky Hill rivers. These beds yield an abundance of satisfactory waters. Over the rest of the county good, soft water is difficult to obtain, for, except in the northern part, where there are irregular areas of Dakota sandstone, the character of the water is determined by Permian rocks, which generally yield hard waters.

In Table 55 analyses 1, 3, 5, and 7 to 13 represent tests of waters from the *Equus* beds, and should be compared with analyses 2, 3, 5, and 6 and assays 1 to 4, Harvey County (Table 38), which are tests of waters from the same beds. Of the waters from the *Equus* beds in McPherson County, analyses 1, 3, 4, 5, 7, 8, 10, and 11 (Table 55) show calcic alkaline waters, analysis 9 shows a sodic calcic alkaline water, and analyses 12 and 13 show calcic sodic alkaline waters. Of the calcic alkaline waters analyses 1, 3, 7, 10, and 11 indicate waters of high temporary and considerable permanent hardness, analyses 4 and 5 waters of high temporary and low permanent hardness, and analysis 8 shows a very satisfactory water of low temporary and low permanent hardness. A calcic saline water so highly mineralized as to be unfit for ordinary use is shown by analysis 6 and a calcic saline water so hard as to be unsatisfactory for use in steam boilers is shown by analysis 6. It is probable that neither of these waters comes from the *Equus* beds. The superiority of well waters from the *Equus* beds to well waters from the Permian deposits in McPherson and Harvey counties may be appreciated by comparing the waters from these beds with analysis 2 of McPherson County and analysis 1 of Harvey County.

The assays of samples from Marquette are interesting, because they show a peculiarity of the well waters in the city, namely, that those north of Smoky Hill River are free from iron, whereas those south of it contain so much iron as to be most troublesome to the householders. The cause of this difference in the well waters is not certainly known, but it may be that the waters of the wells north of the river come from the *Equus* beds, which do not appear to yield water of a high iron content, while the wells south of the river are supplied with water from the unconsolidated material at the edge of the river, which water often contains much iron, as tests of well waters from this material at Salina, Manhattan, Topeka, Lawrence, and Argentine show.

77836°—WSP 273—11——9

TABLE 55.—*Analyses and assays of underground waters from McPherson County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1902. Sept. 19 | Canton, well | | Atchison, Topeka & Santa Fe Ry. | 22 | | 84 | 19 | 31 | 171 | | 49 | | 12 | | |
| 2 | | Conway, well | | G. H. Failyer and C. M. Breese. [a] | 14 | [b] Tr. | 521 | 95 | (Na) 39; (K) 19 | | | 1,655 | | 60 | | 2,408 |
| 3 | 1908. Sept. | Galva, well | 47 | Chicago, Rock Island & Pacific Ry. | | [c] 3.6 | 90 | 15 | 35 | 153 | | 57 | | 33 | | 387 |
| 4 | 1902. Dec. 8 | Groveland, well | | do | 21 | 2 | 107 | 10 | 34 | 180 | | 8.2 | | 51 | | |
| 5 | 1908. Sept. | do | 90 | do | | [c] 7.7 | 111 | 14 | 35 | 160 | | 28 | | 83 | | 440 |
| 6 | 1906. Nov. 21 | Lindsborg, city waterworks, 4 wells. | 60 | F. W. Bushong [d] | 17 | 1.1 | 112 | 20 | 32 | .0 | 390 | 164 | 0.45 | 111 | | 666 |
| 7 | 1902. Sept. 30 | McPherson, well | | Kennicott Water Softener Co. | 34 | | 128 | 10 | 26 | 168 | | 44 | | 67 | | |
| 8 | 1904. Aug. 31 | McPherson, well of McPherson Ice Manufacturing Co. | | do | 38 | 1 | 93 | 8.3 | 5.9 | 147 | | 13 | | 15 | | |
| 9 | 1906. Nov. 21 | McPherson, city waterworks, 4 wells. | 150 | F. W. Bushong [d] | 21 | [e] .2 | 94 | 5.2 | 128 | .0 | 343 | 1 | 1.3 | 25 | | 331 |
| 10 | | Marquette, 2 wells | 46 | Missouri Pacific Ry | 27 | 2.2 | 110 | 24 | 35 | 217 | | 63 | | 16 | 14 | 510 |
| 11 | 1908. June 11 | Mound Ridge, well | 22 | Kennicott Water Softener Co. [f] | | | 80 | 15 | 49 | 165 | | 34 | | 39 | | |
| 12 | do | do | 22 | do. [g] | 14 | 1.4 | 106 | 21 | 96 | 195 | | 110 | | 85 | | |
| 13 | do | do | 20 | do. [h] | 12 | 2.7 | 154 | 36 | 128 | 228 | | 104 | 74 | 145 | | |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | 1907. Dec. 23 | Marquette, 4 wells of Marquette waterworks. | 39 | | | .0 | | | | .0 | 310 | Trace. | | 26 | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | ........ | Marquette, well of Chas. Anderson, NE. ¼ sec. 26, T. 17 S., R. 5 W.[i] | 35 | ........ | ........ | 9.0 | ........ | ........ | ........ | .0 | 467 | 328 | ........ | 229 | ........ | ........ |
| 3 | ........ | Marquette, well of J. Gust Peterson, NE. ¼ sec. 26, T. 17 S., R. 5 W. | ........ | ........ | ........ | 3.0 | ........ | ........ | ........ | .0 | 369 | 328 | ........ | 114 | ........ | ........ |
| 4 | ........ | Marquette, well of H. A. Van Horne, lot 4, block —, Bacon Addition.[i] | 35 | ........ | ........ | 1.5 | ........ | ........ | ........ | .0 | 386 | 229 | ........ | 140 | ........ | ........ |

[a] Transactions of Kansas Acad. of Science, vol. 11, p. 110.
[b] Al, 5.5.
[c] $SiO_2+Fe_2O_3+Al_2O_3$.
[d] Made at the laboratories of the University of Kansas.
[e] Al, 0.17.
[f] Furnished by Burns & McDonnell, of Kansas City, Mo., from a gravel bed 1½ to 3 feet thick.
[g] Furnished by Burns & McDonnell, of Kansas City, Mo., from a gravel bed 1½ to 3 feet thick like preceding sample, but taken on west side of Black Kettle Creek.
[h] Furnished by Burns & McDonnell, of Kansas City, Mo.
[i] On south side of Smoky Hill River.

## MARION COUNTY.

All of Marion County is underlain by Permian rocks, and in certain parts of it gypsum deposits are found; hard waters are therefore to be expected.

All of the analyses (Table 56) show waters of high temporary hardness, and they all show waters of very great permanent hardness except analysis 4, which indicates a water of low permanent hardness. Waters of the calcic alkaline class are shown by analyses 1, 2, 4, 5, and 10. A calcic magnesic alkaline water is indicated by analysis 6, a calcic saline water by analysis 3, a calcic sodic saline water by analysis 9, and calcic magnesic saline waters are shown by analyses 7 and 8. The assays all show exceptionally hard waters.

TABLE 56.—*Analyses and assays of underground waters from Marion County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1902. Dec. 16 | Durham, Chicago, Rock Island & Pacific Ry. well. | ........ | Kennicott Water Softener Co. | 26 | 35 | 610 | 79 | 100 | 678 | ......... | 867 | 24 | ........ | ........ |
| 2 | 1908. Sept. | .....do | 25 | Chicago, Rock Island & Pacific Ry. | ........ | a 8.9 | 105 | 34 | 19 | 180 | ......... | 121 | 10 | ........ | 477 |
| 3 | 1897. Apr. 6 | Florence, Atchison, Topeka & Santa Fe Ry. well. | ........ | Atchison, Topeka & Santa Fe Ry. | 22 | ...... | 261 | 14 | 28 | 212 | ......... | 342 | 44 | 77 | 1,001 |
| 4 | 1902. Nov. 10 | Florence, spring of H. Jones | ........ | .....do | 29 | ...... | 116 | 21 | 38 | 211 | ......... | 23 | 58 | 46 | 539 |
| 5 | 1897. Apr. 12 | Peabody, Atchison, Topeka & Santa Fe Ry. well. | ........ | .....do | 22 | ...... | 258 | 14 | 22 | 285 | ......... | 220 | 34 | 113 | 971 |
| 6 | 1901. Apr. 5 | Peabody, city waterworks, 8 wells | 30-36 | .....do | ........ | ...... | 144 | 41 | 3.3 | 177 | ......... | 215 | 14 | 68 | 652 |
| 7 | ...do.... | Peabody, well south of depot | ........ | .....do | ........ | ...... | 314 | 77 | 14 | 201 | ......... | 650 | 84 | 205 | 1,541. |
| 8 | 1904. Mar. 21 | Peabody, private well | ........ | .....do | 20 | 2.4 | 205 | 64 | 14 | 220 | ......... | 343 | 57 | 190 | 1,118 |
| 9 | ...do.... | Peabody, stockyards well | ........ | .....do | 31 | 22 | 87 | 34 | 86 | 144 | ......... | 163 | 98 | 216 | 890 |
| 10 | 1902. Sept. 25 | Marion, city well | ........ | .....do | 29 | Tr. | 134 | 34 | 24 | 158 | ......... | 212 | 30 | ........ | ........ |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1905. July 28 | Florence, well 2 miles north and 2 miles west of city. | 20 | Edward Bartow | ........ | .0 | ...... | ...... | ......... | .0 | 488 | 46 | 21 | ........ | ........ |
| 2 | ...do.... | Marion, well 2 miles north of city | ........ | .....do | ........ | .0 | ...... | ...... | ......... | .0 | 421 | 66 | 12 | ........ | ........ |
| 3 | ...do.... | Marion, well 2 miles north and 3 miles west of city. | Shallow. | .....do | ........ | .0 | ...... | ...... | ......... | .0 | 385 | 53 | 14 | ........ | ........ |
| 4 | ...do.... | Marion, spring in Central Park | ........ | .....do | ........ | .0 | ...... | ...... | ......... | .0 | 400 | 222 | 51 | ........ | ........ |
| 5 | 1907. Aug. 12 | .....do | ........ | | ........ | .0 | ...... | ...... | ......... | .0 | 400 | 256 | 65 | ........ | ........ |
| 6 | 1905. July 27 | Peabody, city supply, 6 wells | 30-36 | Edward Bartow | ........ | .0 | ...... | ...... | ......... | .0 | 414 | 222 | 24 | ........ | ........ |
| 7 | .......... | Peabody, well in southern part of city. | 15 | .....do | ........ | .0 | ...... | ...... | ......... | .0 | 362 | 530 | 66 | ........ | ........ |

a $SiO_2+Fe_2O_3+Al_2O_3$.

## MARSHALL COUNTY.

Marshall County is underlain by Permian and Pennsylvanian rocks, from which hard waters must be expected. In areas covered by glacial drift, however, wells may obtain somewhat softer water.

Analyses 1 and 2 (Table 57) show calcic magnesic alkaline waters; the former indicates a soft water and the latter one of considerable temporary hardness. Assays 2 and 3 indicate very hard waters. Assay 1, like analysis 1, is a test of the city water at Blue Rapids.

TABLE 57.—*Analyses and assays of underground waters of Marshall County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | .......... | Blue Rapids, city water wells....... | 12 | Missouri Pacific Ry...... | 26 | 0.8 | 72 | 17 | 23 | 140 | ......... | 35 | 21 | 57 | 393 |
| 2 | .......... | Vermilion, well.................... | 40 | .....do.................. | 43 | 2.2 | 87 | 25 | 23 | 192 | ......... | 30 | 14 | 28 | 444 |
| | | ASSAYS. | | | | | | | | | | | | | |
| | 1907. | | | | | | | | | | | | | | |
| 1 | Feb. 15 | Blue Rapids, city supply, 3 wells [a] .. | 12 | ........................ | ........ | Tr. | ...... | ........ | .......... | .0 | 278 | Trace. | 30 | ........ | ........ |
| 2 | Feb. 16 | Frankfort, well of Savoy Hotel...... | 35-45 | ........................ | ........ | .0 | ...... | ........ | .......... | .0 | 473 | 214 | 55 | ....... | ........ |
| 3 | Feb. 18 | Marysville, city supply [b]........... | 42 | ........................ | ........ | Tr. | ...... | ........ | .......... | .0 | 464 | 113 | 110 | ...... | ........ |

[a] Tap in Hotel Waldeau.

[b] Tap in Pacific Hotel.

## MEADE COUNTY.

In Crooked Creek valley, from Meade to Wilburn, many flowing wells, 50 to 250 feet deep, obtain water from Tertiary and Quaternary deposits. The water is much used for irrigation, but its pressure is slight. The northwestern corner of Meade County is underlain by Dakota sandstone, which yields waters to wells of moderate depth. Underlying the entire county and appearing in the valleys to the southeast are "Red Beds." One boring at Meade, a little over 800 feet deep, passed through 250 feet or more of Tertiary clay and sands and then Red Beds and gypsum to the bottom. No good water was obtained.[1]

The Meade artesian area is fully described on pages 40–43. The only complete analysis (Table 58) is of a well water in Meade. The analysis shows a soft calcic alkaline water and should be compared with analysis No. 2 (Table 13), Clark County, assays 1 to 23, 25, 27, 28, and 29 (Table 58), Meade County, and also with the assays of wells in Haskell County (Table 39), for they are very much alike. The evidence that they furnish tends to substantiate Erasmus Haworth's opinion that the water of the flowing wells in Crooked Creek Valley is derived from the "underflow" that is slowly moving southeastward over the Cretaceous floor.

The flowing wells in the Meade artesian area are wonderfully alike. The temperature taken with a thermometer was found to vary between 14.5° and 16° C. and that of most of the wells was between 15.5° and 16° C. The chlorine content of the waters of these wells is remarkably constant, and in no case was the $SO_4$ as great as 35 parts per million. There is some variation in the amount of $HCO_3$, though not much. The waters, of which assays 1 and 5 are tests, are peculiar in that they have a distinct odor of sulphureted hydrogen. The two wells that yield these waters are in the northeast corner of the valley. W. W. Cockins, jr., states that the flow of the wells in the valley of Crooked Creek varies from almost nothing to 80 gallons per minute, but that the average flow is about 12 gallons per minute, the flow of most of the wells being confined between 8 and 15 gallons. Wells that flow 30 to 45 gallons a minute are not uncommon. Some of the wells that are artesian do not flow. Usually this is due to the fact that the mouths of the wells are higher than those of flowing wells near by, or to the choking of the wells by sand, but sometimes the reason why wells fail to flow is not apparent. The number of flowing wells in the valley is not known. Some estimate that there are 200 of them, while others are confident that

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 307.

there are over 300. In all of the flowing wells the water is soft, cool, and wholesome.[a]

Assay 28 (Table 58) is a test of a shallow-well water in Meade and is believed to be representative of that water of which Haworth says:

The whole of the artesian valley is supplied with the ordinary underground water, which may be found at from 5 to 15 feet below the surface. Its abundance is not known as no one cares to use it. It would seem that it is sharply distinguished from the deeper lying artesian water, as it has no apparent artesian properties.[b]

The assay shows a very soft water very much like the artesian water. Assays 24 and 26 are tests of waters outside of the artesian area. They indicate very hard waters which are very high in chlorides.

Assay 29 is a test of the famous Meade salt well. No analyses or assays of the water of Meade County represent wells in the Dakota sandstone.

TABLE 58.—*Analysis and assays of underground waters from Meade County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1908. Sept. | Meade, well | 45 | Chicago, Rock Island & Pacific Ry. | c1.4 | 49 | 14 | 9.6 | 98 | .... | 28 | 6.7 | 208 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1907. Oct. 31 | Fowler, NE. ¼ sec. 4, T. 30 S., R. 26 W., flowing well of A. D. Walker.[d] | 140 | 0.0 | 0.0 | 241 | Trace. | 10 |
| 2 | ...do.... | ...do.[e] | 140 | .0 | .0 | 236 | Trace. | 10 |
| 3 | ...do.... | Wilburn, SE. ¼ sec. 4, T. 30 S., R. 26 W., flowing well of A. D. Walker.[f] | 65 | .0 | .0 | 236 | Trace. | 15 |
| 4 | ...do.... | Meade, NE. ¼ sec. 12, T. 30 S., R. 28 W., flowing well of Frank Leach. | 160 | .0 | .0 | 207 | Trace. | 10 |
| 5 | ...do.... | Fowler, NW. ¼ sec. 23, T. 30 S., R. 26 W., well of M. M. Way.[g] | 175 | .0 | .8 | 312 | Trace. | 4 |
| 6 | ...do.... | Meade, NE. ¼ sec. 29, T. 30 S., R. 27 W., flowing well of J. J. Miller.[h] | 100 | .0 | .0 | 197 | Trace. | 10 |
| 7 | ...do.... | Fowler, SW. ¼ sec. 29, T. 30 S., R. 26 W., flowing well of John Syms.[i] | 120 | .0 | .0 | 185 | Trace. | 10 |

[a] The Meade artesian area is described by Erasmus Haworth in Water-Supply Paper U. S. Geol. Survey No. 6, 1897, pp. 48–56.
[b] Water-Supply Paper U. S. Geol. Survey No. 6, 1897, p. 50.
[c] $SiO_2+Fe_2O_3+Al_2O_3$.
[d] 15° C. faint odor of $H_2S$.
[e] No odor of $H_2S$.
[f] 14.5° C.; the shallowest flowing well in the artesian valley.
[g] This well smells strongly of $H_2S$ and does not flow but others at a lower elevation on the place do. They smell faintly of $H_2S$.
[h] 15.8° C.; well farthest northwest in artesian valley yielding a good flow.
[i] The weakest flowing well in the artesian valley.

TABLE 58.—*Analysis and assays of underground waters from Meade County*—Contd.

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS—continued. | | | | | | |
| | 1907. | | | | | | | |
| 8 | Oct. 31 | Fowler, SW. ¼ sec. 32, T. 30 S., R. 27 W., flowing well of Charles Sourbier.[a] | ........ | 0.0 | 0.0 | 185 | Trace. | 10 |
| 9 | ...do.... | Meade, SW. ¼ sec. 33, T. 30 S., R. 27 W., flowing well of S. L. Sawyer.[b] | 125 | .0 | .0 | 197 | Trace. | 10 |
| 10 | ...do.... | Meade, NE. ¼ sec. 5, T. 31 S., R. 27 W., flowing well of Benj. Cox.[c] | 125 | .0 | .0 | 211 | Trace. | 10 |
| 11 | ...do.... | Meade, NW. ¼ sec. 5, T. 31 S., R. 27 W., flowing well of Frank Maas.[d] | 130 | .0 | .0 | 188 | Trace. | 10 |
| 12 | Oct. 30 | Meade, SE. ¼ sec. 14, T. 31 S., R. 28 W., flowing well of G. B. Allen.[e] | 80 | .0 | .0 | 195 | Trace. | 10 |
| 13 | ...do.... | Meade, SE. ¼ sec. 14, T. 31 S., R. 28 W., well of G. B. Allen.[f] | 400 | .0 | .0 | 218 | Trace. | 15 |
| 14 | Oct. 31 | Meade, NW. ¼ sec. 18, T. 31 S., R. 27 W., flowing well of John Shaw. | 160 | .0 | .0 | 204 | Trace. | 10 |
| 15 | Nov. 4 | Plains, NE. ¼ sec. 20, T. 31 S., R. 30 W., well of Jas. Graham.[g] | 128 | .5 | .0 | 188 | Trace. | 15 |
| 16 | Oct. 30 | Meade, SW. ¼ sec. 26, T. 31 S., R. 28 W., flowing well of Mr. Hubbell. | ........ | .0 | .0 | 198 | Trace. | 10 |
| 17 | Oct. 31 | Meade, NE. ¼ sec. 27, T. 31 S., R. 27 W., flowing well of Doctor Oldham.[a] | 320 | .0 | .0 | 198 | Trace. | 10 |
| 18 | Nov. 2 | Meade, SW. ¼ sec. 12, T. 32 S., R. 28 W., flowing well of A. D. Walker.[h] | 150 | .0 | .0 | 180 | Trace. | 10 |
| 19 | ...do.... | Meade, SW. ¼ sec. 17, T. 32 S., R. 28 W., Big Spring near Crooked L Ranch.[a] | ........ | .0 | .0 | 195 | Trace. | 10 |
| 20 | ...do.... | Meade, NE. ¼ sec. 19, T. 32 S., R. 28 W., spring one-half mile west of Big Spring. | ........ | .0 | .0 | 211 | Trace. | 10 |
| 21 | ...do.... | Meade, SE. ¼ sec. 19, T. 32 S., R. 28 W., flowing well on Crooked L Ranch. | ........ | .0 | .0 | 215 | Trace. | 10 |
| 22 | ...do.... | Meade, NW. ¼ sec. 21, T. 32 S., R. 28 W., flowing well in valley of Spring Creek on Crooked Creek.[a] | ........ | .0 | .0 | 204 | Trace. | 10 |
| 23 | ...do.... | Meade, SW. ¼ sec. 22, T. 32 S., R. 28 W., well on Crooked L Ranch. | ........ | .0 | .0 | 235 | Trace. | 15 |
| 24 | ...do.... | Meade, NE. ¼ sec. 34, T. 32 S., R. 28 W., dug well. | ........ | .0 | .0 | 200 | 197 | 1,732 |
| 25 | ...do.... | Meade, NW. ¼ sec. 34, T. 32 S., R. 28 W., flowing well. | ........ | .0 | .0 | 200 | Trace. | 15 |
| 26 | ...do.... | Meade, SE. ¼ sec. 35, T. 32 S., R. 28 W., well. | 160 | 10.0 | .0 | 229 | 78 | 532 |
| 27 | Nov. 3 | Meade, tap in city waterworks, 2 wells.. | {184<br>190} | .0 | .0 | 191 | Trace. | 10 |
| 28 | Nov. 2 | Meade, shallow well of John Wehrle, West Carthage Ave. | 60 | .0 | .0 | 245 | Trace. | 10 |
| 29 | ...do.... | Meade, SE. ¼ sec. 14, T. 32 S., R. 28 W., salt well. | ........ | .0 | 12 | 32 | Trace. | 7,198 |
| 30 | Nov. 4 | Plains, well of Frank M. Paul on SE. ¼ sec. 19, T. 30 S., R. 30 W.[i] | 168 | Tr. | 0.0 | 185 | Trace. | 10 |

[a] 16° C.
[b] 15° C.; the second flowing well sunk in the valley.
[c] At the present time the well has become obstructed with sand and does not flow, but water is easily raised by a pump. This was the first flowing well in the artesian valley and was sunk in August, 1887. (S. Doc. No. 41, pt. 2, appendix 26, 52d Cong., 1st sess., and S. Ex. Doc. No. 222, 51st Cong., 1st sess., pp. 151 and 155.)
[d] 15.5° C.; well is at edge of road in front of house.
[e] Weak flow.
[f] Artesian water entered at 45 feet; the well was sunk to 400 feet in an attempt to get a flow, but none was obtained.
[g] Not in the artesian valley.
[h] 15.8° C.
[i] Put down in 1907.

## MIAMI COUNTY.

As Miami County is underlain by Pennsylvanian rocks, the prospect of finding soft waters is not good, for the rocks of this series and those below it yield highly mineralized waters. C. J. Haffey, who has sunk many oil wells about Paola, stated in conversation that the first oil sand is reached at a depth of 280 to 370 feet, and that in the vicinity of Paola 160 feet of casing shuts out all shallow ground water. He said, too, that 3 miles east of Paola the first water is met at a depth of 65 to 80 feet and that 135 to 140 feet of casing are used to exclude it, while 4 miles southeast of the city 140 feet of casing cuts off all the surface water. Mr. Haffey reported salt water as being encountered at a depth of 400 to 500 feet. It is commonly believed that in the oil region of Miami County many wells of moderate depth have been spoiled by salt water that has leaked out from the oil wells.

No analyses are presented. Assays 6 and 7, Table 59, show very salty waters and the others hard ones.

TABLE 59.—*Assays of underground waters from Miami County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | | |
| 1 | June 22 | Osawatomie, Haskins's well, south side of Main Street | | 0.0 | 0.0 | 284 | 91 | 127 |
| 2 | ...do..... | Osawatomie, Mrs. Roberts's well, north side of Brown Avenue | 30 | .0 | .0 | 221 | 77 | 132 |
| 3 | ...do..... | Osawatomie, Gates's well, north side of Brown Avenue (shallow) | | .8 | .0 | 157 | 46 | 61 |
| 4 | ...do..... | Osawatomie, spring at State Insane Hospital | | .0 | .0 | 345 | 246 | 25 |
| 5 | June 24 | Paola, spring on Gold Street, 2½ blocks north of public square | | .0 | .0 | 341 | 68 | 35 |
| 6 | June 23 | Paola, Conine well, one-half mile northwest of city | | .0 | .0 | 929 | 0 | 2,822 |
| 7 | ...do..... | Paola, Nicholson well, 1¾ miles northwest of city [a] | 400 | .5 | .0 | 642 | 0 | 5,183 |
| 8 | ...do..... | Paola, Thompson's well, 1 mile northwest of city | 35 | .5 | .0 | 167 | 64 | 20 |
| 9 | ...do..... | Paola, Ringer's well, 1¾ miles north of city | 18 | .5 | .0 | 229 | 43 | 15 |
| 10 | ...do..... | Paola, spring at edge of Bull Creek above Ten Mile Creek | | .0 | .0 | 292 | 55 | 4.6 |

[a] Water comes in at 130 feet, below which depth the well is closed.

## MITCHELL COUNTY.

Mitchell County includes a portion of Solomon and Salt Creek valleys. The greater part of its area is occupied by the Benton shales, but to the east Solomon River has cut through these into the Dakota sandstone. A number of wells reach this sandstone and obtain satisfactory supplies but do not flow. At Asherville (?) a well sunk 638 feet obtained abundant very salty water which rose to 26 feet below the surface. This well penetrated 49 feet of sand and clay, 3 feet of sand (Dakota ?), and thence to the bottom was in blue clay and sandstone.

A well near Bluehill is reported to be 308 feet deep and to pass through Benton shales into Dakota sandstone. Good water was found, which at first rose to the top of the well and then settled down again. A boring made 2 miles northeast of Cawker, sunk to determine the presence of coal, is said to be 467½ feet deep. Fresh water was reported at 460 feet, but it mixed with the salty water from the higher horizon (213 to 215½ feet) so that it was not utilized. The water rose to within 227 feet of the surface. The salty water was undoubtedly from the saliferous shales which usually occur immediately under the Benton shales; the lower water was doubtless derived from the Dakota sandstone.[1]

The only analyses presented in Table 60 are of the waters of the famous Great Spirit Spring and of Waconda No. 2, both of which are described in volume 7, pages 197–206, of the Kansas University Geological Survey. The two assays show very hard waters.

TABLE 60.—*Analyses and assays of underground waters from Mitchell County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | .......... | Waconda, Great Spirit Spring (Waconda No. 1). | ... | E. H. S. Bailey and D. F. McFarland.[a] | 17 | 6 | 144 | 394 | 6,308 | .... | .... | 3,348 | ... |
| 2 | .......... | Waconda, Great Spirit Spring (Waconda No. 2). | ... | E. H. S. Bailey and E. M. Rice.[a] | 15 | ([b]) | 276 | 369 | (Na) 5,589 (K) 178 | .... | .... | 3,236 | ... |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. Sept. 4 | Beloit, well of Beloit Steam Laundry. | 40 | .................. | ... | .0 | ... | ... | ............ | 0.0 | 386 | 191 | 164 |
| 2 | Sept. 5 | Cawker, well of J. W. Higgins south of city and 30 rods from South Fork of Solomon River. | 50 | .................. | ... | .0 | ... | ... | ............ | .0 | 356 | 132 | 39 |

[a] Kansas Univ. Geol. Survey, vol. 7. [b] Al, 8.9.

## MONTGOMERY COUNTY.

Montgomery County is underlain by the Pennsylvanian series, the rocks of which yield highly mineralized waters, as do those of the series below it. There is, therefore, poor prospect for soft waters. There are many oil and gas wells in the county.

Analysis 1, Table 61, shows a very heavily mineralized sodic calcic magnesic saline water and analysis 2 a calcic alkaline water of very great temporary hardness. The assay is a test of a water high in sulphates, bicarbonates, and chlorides.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 307–308.

TABLE 61.—*Analyses and assay of underground waters from Montgomery County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | ........ | Independence bromo-magnesium well.[a] | 1,100 | E. H. S. Bailey[b] .. | 20 | 9 | 2,762 | 1,510 | (Na)23.468 (K)106 | 409 | .... | 240 | 45,081 |
| 2 | ........ | Coffeyville, well of J. Kloehr. | 33 | .....do............ | 24 | 9.5 | 166 | 36 | 8.8 | 662 | .... | 28 | 14 |
| | | ASSAY. | | | | | | | | | | | |
| 1 | 1907. May 3 | Elk, well in front of Eagle drug store. | [c] 11 | .................. | ... | .0 | ..... | ..... | ............ | .0 | 307 | 460 | 146 |

[a] Kansas Univ. Geol. Survey, vol. 7.
[b] Br, 183; I, 1.3.
[c] 11 feet is the usual depth of wells in Elk A 26-foot well, a short distance from this one, was abandoned because the water was so very salty.

## MORRIS COUNTY.

All of Morris County, except the southeast corner, is underlain by the Permian series. The prospect for soft waters is, therefore, not good, for the rocks of this series and those beneath it afford hard waters.

The analyses, Table 62, show calcic magnesic alkaline waters of great temporary hardness. Analysis 4 should be compared with the analyses of the well waters about Herington, as the water was furnished by a committee of citizens of that city who were searching for a water suitable for a public supply. The assays recorded in Table 62 are all tests of waters in the vicinity of Council Grove and show considerable variation in the constituents. Assays 1 and 2 indicate waters of moderate temporary and marked permanent hardness, very high in chlorides. Assay 4 shows a water of high temporary and permanent hardness, very high in chlorides. Assay 6 is a test of a water of great temporary hardness, low permanent hardness, and high in chlorides. Assays 3, 5, and 8 indicate waters of moderate temporary hardness, high permanent hardness, and low chlorides. Assay 7 shows the only soft water in the group of assays.

TABLE 62.—*Analyses and assays of underground water from Morris County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1902. Dec. 8 | Dwight, surface well of Chicago, Rock Island & Pacific Ry. | ........ | Kennicott Water Softener Co. | 22 | 15 | 98 | 25 | 35 | 208 | ........ | 49 | ........ | 17 | ........ |
| 2 | 1908. Sept. | Dwight, east well 50 feet from tank | 30 | Chicago, Rock Island & Pacific Ry. | ........ | a 2.6 | 84 | 23 | 22 | 175 | ........ | 35 | ........ | 15 | 356 |
| 3 | ...do..... | Dwight, west well 50 feet from tank | 30 | .....do | ........ | a 2 | 96 | 24 | 14 | 191 | ........ | 24 | ........ | 18 | 369 |
| 4 | 1907. Aug. 27 | Sec. 7, T. 16 S., R. 5 E., Chalker's well.[b] | 60 | F. W. Bushong | 14 | 13 | 87 | 49 | 35 | 0 | 450 | 50 | 5.5 | 7.5 | 415 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1905. July 29 | Council Grove, public well | ........ | Edward Bartow | ........ | .0 | ........ | ........ | ........ | .0 | 166 | 76 | ........ | 258 | ........ |
| 2 | 1907. Aug. 16 | .....do | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 180 | 115 | ........ | 278 | ........ |
| 3 | ...do..... | Council Grove, well north of courthouse in courthouse yard. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 262 | 113 | ........ | 49 | ........ |
| 4 | ...do..... | Council Grove, well of J. M. Miller on Sixth Street. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 386 | 65 | ........ | 154 | ........ |
| 5 | ...do..... | Council Grove, well at city waterworks pumping station. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 272 | 60 | ........ | 14 | ........ |
| 6 | ...do..... | Council Grove, well of A. B. Robinson on Belfry Hill. | 28 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 312 | Trace. | ........ | 9 | ........ |
| 7 | 1905. July 29 | Council Grove, well 2 miles south of city. | 45 | Edward Bartow | ........ | .0 | ........ | ........ | ........ | .0 | 542 | Trace. | ........ | 238 | ........ |
| 8 | ...do..... | Dunlap, public well | 28 | .....do | ........ | .0 | ........ | ........ | ........ | .0 | 414 | 47 | ........ | 44 | ........ |

a $SiO_2+Fe_2O_3+Al_2O_3$.

b Made at the laboratories of the University of Kansas.

## MORTON COUNTY.

Morton County[1] lies in the extreme southwestern corner of Kansas, along the valley of Cimarron River. The entire county appears to be underlain by Dakota sandstone, which is deeply covered by the Tertiary deposits on the higher lands. Along the Cimarron River bottoms, south and southwest of Richfield, this sandstone yields flowing water in wells 90 to 105 feet deep, but the pressure is very slight and no flow is obtainable on the higher lands. Two wells 50 feet apart were sunk at Richfield to the depths of 651 and 701 feet to obtain flowing water, but the flow obtained was from the "Red Beds" and the water was of unsatisfactory quality. It is stated that the pressure was sufficient to raise the water 125 feet above the surface.

The following record is given:

*Record of well at Richfield, Kans.*

| | Feet. |
|---|---|
| Soil and Tertiary grit (reported as gypsum) | 1–40 |
| Yellow clay and sand | 40–52 |
| Sand | 52–71 |
| Blue joint clay | 71–72 |
| Dakota sandstone with great quantities of water which does not rise much | 72–202 |
| Blue shale | 202–251 |
| Red sandstone with a flow of 6.3 gallons a minute at about 637 feet | 251–701 |

In the southern tier of counties, including Morton, Stevens, Seward, Meade, and Clark counties, the Cimarron River valleys have an aggregate area of about 250 square miles of unusually smooth, even land in which water in great quantities lies at a depth of 10 to 30 feet. A few wells have reached greater depths before obtaining water, but in such wells the water usually rises within 20 or 30 feet of the surface, so that this measurement represents the distance the water will have to be lifted in pumping. In the southwestern part of the State the Dakota water can be reached at shallow depths.[2]

William Easton Hutchinson, of Garden, writes that near the North and South Forks of Cimarron River the wells are very shallow, many of them being less than 10 or 15 feet deep. In the northern part of Morton County, as well as in part of the extreme western section, the depth to water is 100 feet or more, but in nearly all of Morton County good water can be reached at a depth of 45 feet. Two artesian wells were drilled within a half mile of Richfield in 1890 and continued to flow good streams for 10 years, when the flow ceased because of lack of proper attention to the wells.

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 308.

[2] Abstracted from Report of the Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 103.

Neither water analyses nor assays were made in Morton County. E. Dudley, mayor of Liberal, who has had wide experience as a well driller and who has been thoroughly conversant with southeastern Kansas since early pioneer days, says that at Point of Rocks there are three flowing wells. The first of these is 8 miles east of the city; the second is in the city and is a strong alkali water, while the third is 12 miles west of Point of Rocks. Mr. Dudley says further that in Colorado, 6 to 12 miles west of the Colorado-Kansas State line, in the Cimarron bottoms, is a bed of gravel 7 to 12 feet thick that carries water in abundance. A 5-inch pump inserted 1 foot below the top of the gravel failed to lower the water level.

## NEMAHA COUNTY.

Nemaha County is underlain by the Pennsylvanian series whose rocks normally yield hard waters; possibly wells in the glacial drift may prove more satisfactory.

Analysis 1, Table 63, shows a calcic magnesic alkaline water of high temporary and considerable permanent hardness, and analysis 2 indicates a calcic sodic alkaline water of marked permanent hardness. The assay denotes a water of considerable temporary hardness.

TABLE 63.—*Analyses and assay of underground waters from Nemaha County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1908. Sept. | Sabetha, well 50 feet from Chicago, Rock Island & Pacific Ry. tank. | 160 | Chicago, Rock Island & Pacific Ry. | ... | [a] 16 | 89 | 39 | 34 | 208 | .... | 87 | 12 | ... | 485 |
| 2 | .......... | Wetmore, well...... | 44 | Missouri Pacific Ry. | 31 | 2.9 | 86 | 16 | 48 | 139 | .... | 111 | 24 | 72 | 530 |
| | | ASSAY. | | | | | | | | | | | | | |
| 1 | 1907. July 22 | Seneca, city water [b].. | 6[illegible] | .................... | ... | .0 | ... | ... | .... | .0 | 278 | Tr. | 20 | ... | ... |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.  [b] Tap in Hotel Gilford.

## NEOSHO COUNTY.

As Neosho County is entirely underlain by Pennsylvanian rock, the prospect of finding soft water is poor.

In Table 64 the only analysis is a test of a very hard laxative calcic sodic alkaline well water at Erie. Assays 8 and 11 are the only ones that indicate soft water. Assay 5 shows the hardest water of those tested in the county, both the temporary and permanent hardness being remarkably high. The temporary hardness of the water, of which 10 is an assay, is very great and the water is high in chlorides. Assay 2 indicates a water of low permanent and rather high temporary hardness. The other waters assayed are very hard indeed.

TABLE 64.—*Analysis and assays of underground waters from Neosho County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | | |
| 1 | 1902. Nov. 7 | Erie, well.......... | ... | Atchison, Topeka & Santa Fe Ry. | 18 | 1.7 | 156 | 31 | 134 | 247 | .... | 257 | 95 | 18 |

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | | |
| 1 | 1905. July 22 | Chanute, public well.......................... | 30 | E. Bartow.. | 0.0 | 0.0 | 177 | 42 | 139 |
| 2 | July 21 | Chanute, well at Kansas & Texas Oil Co. pumping station, 4 miles north of city. | 112 | .....do...... | .0 | .0 | 321 | Tr. | 288 |
| 3 | ....do.... | Chanute, well 3 miles south and 1 mile east of city. | 70 | .....do...... | .0 | .0 | 353 | 121 | 16 |
| 4 | July 19 | Erie, well in southeastern city limits.......... | 25- 30 | .....do...... | .0 | .0 | 396 | 208 | 31 |
| 5 | 1907. Apr. 27 | Erie, Great North Western Oil Co.[a]......... | 98 | ............... | .0 | .0 | 616 | .... | 240 |
| 6 | 1905. July 19 | Erie, well at Atchison, Topeka & Santa Fe Ry. depot. | 90 | E. Bartow.. | 12.0 | .0 | 403 | 328 | 109 |
| 7 | ....do.... | St. Paul, public well.......................... | 35 | .....do...... | .0 | .0 | 363 | 106 | 34 |
| 8 | ....do.... | St. Paul, upland well 3 miles north of city... | 25 | .....do...... | .0 | .0 | 255 | Tr. | 6.5 |
| 9 | July 22 | Shaw, well 3 miles north and 1 west of city.. | 75-100 | .....do...... | 4.0 | .0 | 310 | 113 | 12 |
| 10 | ....do.... | Shaw, well 1 mile east of city................ | 62 | .....do...... | .0 | .0 | 763 | Tr. | 468 |
| 11 | ....do.... | Shaw, spring in pasture southeast of city[b]... | ...... | .....do...... | .0 | .0 | 310 | Tr. | 12 |

[a] Well put down in July, 1906. $SO_4$ much greater than 626. Sample taken from hydrant.
[b] Sold in city.

## NESS COUNTY.

The central, southern, and eastern sections of Ness County are underlain by Benton shales. To the north and west the Benton passes beneath the edge of the Niobrara formation, which is overlain on the higher ridges by Tertiary grit. Probably the Dakota sandstone is at the surface, or a very short distance below, on Pawnee Fork in the southeastern part of the county, and it underlies a region northward at depths which gradually increase to slightly over 500 feet on the divide between the head of Walnut Creek and Smoky Hill

River. The town of Ransom on this ridge has a well 653 feet deep, which passes into Dakota sandstone at 580 feet and obtains a plentiful supply of soft water, rising to within 60 feet of the surface. The rock is described as a soft, porous brown sandstone overlain by several hundred feet of the blue shale of the Benton formation.

Ten miles southwest of Ness, in the northwest corner of T. 20, R. 24, a well 450 feet deep reached Dakota sandstone and obtained a satisfactory supply of soft water.

Twelve miles southwest of Ness, in the southwest corner of T. 19, R. 25, a well 437 feet deep passed through shale and clay into the Dakota sandstone at 370 feet and obtained a satisfactory water supply. At Riverside, 12 miles southeast of Ness, a well 350 feet deep obtains water from the Dakota sandstone. A well 6 miles southwest of Danby is 385 feet deep and passes through 330 feet of shale into sand rock, which yields water rising within 110 feet of the surface. A well 10 miles southwest of Ness (sec. 11, T. 20, R. 24) has a depth of 300 feet.

These representative wells indicate the general relations of the Dakota sandstone in this county. The occurrence of the water is general and its quality good, but no flows are obtainable. The underlying "Red Beds" appear not to have been reached and, although the water which they contain may be expected to be under considerable pressure, its quality usually is bad.[1]

In the vicinity of Ness City different wells carried to a depth of from 250 to 300 feet have obtained water from the Dakota sandstone. No well has yet been drilled in Ness County, which obtained a flow at the surface, but in all of them the water would rise to within 35 to 60 feet of the surface so that it could easily be pumped.[2]

In some parts of the county other waters than those drawn from the Dakota sandstone are available.

Along Walnut Creek, in Ness County, the wide valley is filled with Tertiary materials, beneath which there seems to be great quantities of water. In this valley the water is continuous eastward throughout its entire length. As the Tertiary is passed, other accumulations of loose material occur, so that the proper conditions obtain throughout the entire distance for the accumulation and maintenance of a strong body of water. In passing laterally either north or south from Ness City we come upon the Cretaceous formations. Southward there is but little Tertiary within many miles, and a corresponding lack of water, excepting as it is drawn from the Dakota sandstone over 200 feet below. Northward the high bluffs are composed of the Niobrara chalk, on top of which is a mantle of Tertiary which soon reaches sufficient thickness to become a great water-bearing formation. As a result there is a belt of Tertiary material between Walnut Creek and Smoky Hill River throughout the whole width of Ness County, and even beyond, which has large quantities of water within easy reach of the surface.

* * * * * * *

[1] Description abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 309–310.

[2] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 66.

Along the Missouri Pacific Railway from Pendennis to Utica, Ransom, and Brownell there is an eastern extension of the Tertiary, which is the level upland between the headwaters of the streams which flow into the Walnut to the south and the short canyon which flows into Smoky Hill River. Near the borders of this area the Tertiary is comparatively thin, but in the central portion of it the wells are from 65 to 85 feet deep, extending into the sheet water of the underflow, the exact thickness of the Tertiary not being determinable since the wells are dug no deeper than is required to obtain an abundant supply of water.[1]

The only analyses available are tests of two waters from shallow wells in the Tertiary in the northeastern part of the county. Calcic alkaline waters are indicated by analyses 1 and 2, Table 65, analysis 1 showing a water of moderate and analysis 2 one of high temporary hardness.

Assays 1, 3, 5, 6, 7, 8, and 9 are all tests of wells that draw their water from the Dakota sandstone. From the high chlorides and sulphates it is evident that these wells tap the saliferous and gypsiferous shales of the Dakota sandstone. It is probable that the wells would be improved by casing out this highly mineralized water and sinking them deeper into the sandstone. Assays 2 and 4, Table 65, are tests of the waters of shallow wells; assay 2 shows a very hard water and assay 3 the softest well water assayed in the county.

[1] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, pp. 86, 111.

TABLE 65.—*Analyses and assays of underground waters from Ness County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | .......... | Brownell, wells | 96 | Missouri Pacific Ry. | 45 | 1 | 56 | 11 | 16 | 113 | ........ | 20 | 9.6 | 21 | 294 |
| 2 | .......... | Waring, 3 wells | 20 | ....do.... | 2.4 | 18 | 76 | 15 | 25 | 160 | ........ | 27 | 8.3 | 7.5 | 347 |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Dec 10 | Ness well of Arlington Hotel | 295 | ........ | ........ | .0 | ...... | ........ | ........ | .0 | 262 | 160 | 210 | ........ | ........ |
| 2 | Dec. 9 | Ness, public well on Main Street, near bank building. | 50 | ........ | ........ | Tr. | ...... | ........ | ........ | .0 | 245 | 530 | 342 | ........ | ........ |
| 3 | ...do.... | Ness, well of Dr. Granville-Egerton | 268 | ........ | ........ | Tr | ...... | ........ | ........ | 21 | 249 | 276 | 241 | ........ | ........ |
| 4 | ...do.... | Ness, well of H. Snyder | 40 | ........ | ........ | .0 | ...... | ........ | ........ | .0 | 323 | 50 | 10 | ........ | ........ |
| 5 | 1908. Jan. 14 | Ness, well of Van De Grift, NE. ¼ sec 1, T. 18 S., R. 23 W. | 400 | ........ | ........ | .0 | ...... | ........ | ........ | .0 | ........ | 255 | 252 | ........ | ........ |
| 6 | 1907. Dec. 10 | Ness, well of Mr. Hopper, SE. ¼ sec. 7, T. 18 S., R. 23 W. | *a* 385 | ........ | ........ | Tr. | ...... | ........ | ........ | .0 | 408 | 246 | 306 | ........ | ........ |
| 7 | ...do.... | Ness, well of Mr. Emett, NW. ¼ sec. 20, T. 18 S., R. 23 W. | 300 | ........ | ........ | Tr. | ...... | ........ | ........ | .0 | 295 | 265 | 276 | ........ | ........ |
| 8 | Jan. 18 | Ness, well of J. Maranville, SW. ¼ sec. 23, T. 19 S., R. 23 W. | 257 | ........ | ........ | 0 | ...... | ........ | ........ | .0 | 462 | (*b*) | 1,411 | ........ | ........ |
| 9 | Dec. 10 | Ness, well of Mr. Shepherd, NW. ¼ sec. 25, T. 19 S., R. 24 W. | 300 | ........ | ........ | 0 | ...... | ........ | ........ | .0 | 317 | 265 | 392 | ........ | ........ |

*a* Water from Dakota sandstone.

*b* $SO_4$ greater than 626.

## NORTON COUNTY.

Norton County comprises portions of the valleys of Sappa and Prairie Dog creeks and of the North Fork of Solomon River and the intervening divides. Apparently its entire area is underlain by the Niobrara chalk (which appears in the deeper wells), the intervening divides being covered with Tertiary deposits. The formations all appear to rise gradually to the west on a low anticline, whose summit extends north and south along the western line of the county. In the eastern part of the county the Dakota sandstone is probably about 750 feet below the surface in the valleys and 150 feet deeper on the divides. In the valleys in the western portion of the county it lies about 900 feet deep and on the divides 200 feet deeper.

No deep borings have been reported from this county, but the results of the deep boring at Jennings and Kanona, in the next county west, indicate that the Dakota sandstone contains a large volume of water under moderate head which may possibly afford a flow in the deeper valleys.[1]

All the analyses and assays presented in Table 66 represent tests of shallow wells in the valley of Prairie Dog Creek. A wide discrepancy is exhibited by the analysis and assays of the city water of Norton, for, according to the former, the permanent hardness is marked, whereas the latter shows it to be insignificant. No explanation is offered as to the reason for the difference between the analysis and assay, but perhaps one might be found if the conditions under which the samples were taken were investigated. The other tests show waters of high temporary and slight permanent hardness.

TABLE 66.—*Analyses and assays of underground waters from Norton County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | 1909. .......... | Norton, city water, 4 wells. | 35-60 | Chicago, Burlington & Quincy R. R. | [b] 48 | 169 | 28 | 34 | 250 | .... | 131 | 40 | .... |
| 2 | Sept. | Norton, well.......... | 6 | Chicago, Rock Island & Pacific Ry. | [b] 7.9 | 89 | 18 | 15 | 164 | .... | 37 | 15 | 347 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. Oct. 6 | Norton, city waterworks well, 1,400 feet from Prairie Dog Creek. | 35 | .................. | .0 | .... | .... | .... | .0 | 472 | Tr. | 20 | .... |
| 2 | ...do..... | Norton, city waterworks well at edge of Prairie Dog Creek. | 61 | .................. | 1.0 | .... | .... | .... | .0 | 386 | Tr. | 15 | .... |
| | ...do..... | .....do.............. | 43 | .................. | 1.0 | .... | .... | .... | .0 | 369 | Tr. | 15 | .... |

[a] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 310.
[b] $SiO_2+Fe_2O_3+Al_2O_3$.

## OSAGE COUNTY.

Osage County is underlain by Pennsylvanian rocks, which usually yield highly mineralized waters.

Both the analysis and assays in Table 67 show very hard waters. The analysis indicates a water of the calcic magnesic saline class. The softest water tested is that of the public well in Quenemo. Assay 4 exhibits the most highly mineralized water in the group of assays, for it carries much greater amounts of bicarbonates and chlorides than are carried by the other waters, and it is also very high in sulphates.

TABLE 67.—*Analysis and assays of underground waters from Osage County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$) | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1902. Nov. 7 | Burlingame, well | ... | Atchison, Topeka & Santa Fe Ry. | 22 | 23 | 97 | 37 | 20 | 69 | .... | 266 | 33 |

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | | |
| 1 | 1905. June 13 | Burlingame, well at laundry on Main Street. | ...... | .............. | Tr. | 0.0 | 347 | 492 | 158 |
| 2 | ...do..... | Burlingame, well of Martin Lund... | ...... | .............. | 2.5 | .0 | 367 | ...... | 204 |
| 3 | June 19 | Melvern, public well near the creamery. | 20 | E. Bartow.. | .8 | .0 | 318 | 115 | 138 |
| 4 | June 14 | Osage, city well on south side of Market Street west of Fourth Street. | ...... | .............. | .5 | Tr. | 695 | 222 | 500 |
| 5 | June 20 | Quenemo, public well at Third and Maple Streets. | ...... | E. Bartow.. | .8 | .0 | 347 | 68 | 30 |
| 6 | ...do..... | Quenemo, well at sanitarium of Dr. O. Robertson. | ...... | .....do...... | 2.5 | .0 | 434 | 157 | 66 |

## OSBORNE COUNTY.

Osborne County lies mainly on the Benton shale, which passes under the Niobrara chalk to the west, the beds dipping very gently to the north. The depth to the Dakota sandstone in this county ranges from a very few feet in its southeast corner to about 500 feet on the divides in the extreme western and northwestern sections. A number of borings have been made, of which some appear to have reached the Dakota sandstone and to have found satisfactory water, while a number of others have not been quite deep enough and have been discontinued on encountering salt water, apparently in the shales underlying the Benton. A well of this character at Osborne, 301 feet deep, found very salty water, which rose to within 30 feet of the surface. The well passed entirely through shale, and no sandstone is reported. A well 9 miles south by east from Osborne (NW. ¼ sec. 3, T. 8 S., R. 12 W.), 360 feet deep, found a large volume of salty water, which rises to within 45 feet of the surface. On Solomon River, 6 miles northeast of Osborne (NE. ¼ sec. 14, T. 6 S., R. 12 W.), a well 315 feet deep, passed through blue shale and obtained a large volume of salty water which comes to the surface, and, it is claimed, rose several feet above it when the well was first opened.

These wells indicate that an extensive stratum of water-bearing material lies at the base of the Benton shale, yielding water too salty for use. Doubtless wells bored through this horizon into the deeper beds of the Dakota sandstone would obtain satisfactory water for pump wells.[1]

Analysis 1 (Table 68) is a test of a soft water from the valley of South Fork of Solomon River, and analysis 2 of a hard one in the valley of the North Fork. Assays 1, 3, and 4 denote waters of high temporary and low permanent hardness, and assays 2 and 5 indicate waters of high permanent and temporary hardness.

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[1] Description abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 310.

TABLE 68.—*Analyses and assays of underground waters from Osborne County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | .......... | Alton, well | 35 | Missouri Pacific Ry | 19 | 0.7 | 71 | 9.3 | 33 | 124 | .......... | 30 | 35 | 9.8 | 333 |
| 2 | .......... | Downs, well | 40 | do | 35 | 2.7 | 107 | 12 | 27 | 177 | .......... | 54 | 17 | 89 | 523 |
| | | ASSAYS. | | | | | | | | | | | | | |
| | 1907. | | | | | | | | | | | | | | |
| 1 | Sept. 4 | Downs, well at Ray and Morgan Streets.[a] | 33 | .......... | .......... | .0 | .......... | .......... | .......... | .0 | 400 | Trace. | 19 | .......... | .......... |
| 2 | Sept. 6 | Downs, city waterworks well[b] | 70 | .......... | .......... | .0 | .......... | .......... | .......... | .0 | 356 | 74 | 24 | .......... | .......... |
| 3 | Sept. 7 | Osborne, city waterworks well | 54 | .......... | .......... | .0 | .......... | .......... | .......... | .0 | 369 | Trace. | 19 | .......... | .......... |
| 4 | Sept. 9 | Natoma, well of G. S. Welling in bottoms of Paradise Creek. | 32 | .......... | .......... | .0 | .......... | .......... | .......... | .0 | 344 | Trace. | 14 | .......... | .......... |
| 5 | ...do... | Natoma, schoolhouse well on upland above Paradise Creek.[c] | 85 | .......... | .......... | .0 | .......... | .......... | .......... | .0 | 462 | 74 | 39 | .......... | .......... |

[a] "First water."  [b] "Second water."  [c] Water at 60 feet.

## OTTAWA COUNTY.

Ottawa County, which comprises a portion of the lower valley of Solomon River, is underlain chiefly by Dakota sandstone, but in the deeper valleys in the southern portion of the county the underlying Permian shales are exposed. Many wells in this county penetrate the sandstone to depths ranging from 20 to 150 feet, and generally obtain satisfactory water supplies. Deeper wells would pass into the salt-bearing shales which underlie the Dakota sandstone and which do not contain good water.[1]

The waters of Ottawa County are very inadequately represented by a single assay (Table 69), that of the wells of the city waterworks at the edge of Solomon River. The water has moderate temporary and decided permanent hardness.

TABLE 69.—*Assay of underground water from Ottawa County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| 1 | 1907. Sept 2 | Minneapolis, city waterworks wells and galleries; water derived from sand rock | 57 | 0.0 | 0.0 | 272 | 44 | 29 |

## PAWNEE COUNTY.

Pawnee County embraces a portion of the valleys of Arkansas River and Pawnee Fork. All the lower lands are underlain by Dakota sandstone, but the ridge in the northern portion of the county is capped by a thin bed of Benton shales. Along the river there are extensive alluvial deposits, and to the south are sand dunes and Tertiary beds. Many shallow wells obtain from the Dakota sandstone water which rises to within a few feet of the surface. At Larned is a well 743 feet deep, from which there is a flow of 250 gallons per minute of very saline water. It is reported that fresh water was found in the Dakota sandstone near the surface, a slightly saline flow at 430 feet, and a strong brine under a pressure of 23½ pounds at 743 feet.[1]

According to George I. Adams,[2] the valleys of Pawnee Creek and its tributaries are filled with fluviatile materials which form an important source of water supply. The value of this aquifer depends on its depth, for along the main stream and in the broader valleys, where the material is thick, the water is never failing, but elsewhere the

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p 311.

[2] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, pp 104–107.

aquifer is thin and can not be so confidently relied on. In the eastern portion of the Pawnee bottoms, including the area drained by Sawmill Creek, the thickness of the fluviatile deposits is about 40 feet.

Analysis 2 (Table 70) shows the composition of the flowing salt well near the mouth of Pawnee Creek, and assay 5 is a test of the same water. The chlorine figure of the assay is lower than that of the analysis, which may be due to the fact that since the analysis was made the casing of the well has been so corroded that an opportunity for fresh waters to enter the well and dilute the chlorides now exists. Analysis 9 shows that the city water of Larned may be classed as a calcic sodic saline water; it is hard and has a laxative effect on those unaccustomed to its use. The low chlorides make it apparent that the water is unaffected by that of the salt well. Analyses 3, 7, 11, and 12 indicate waters contaminated by leakage from the salt well. Analysis 5 shows a sodic saline water. Analyses 4, 10, 14, and 15 are tests of sodic calcic saline waters. These waters it is evident are removed from the influence of the salt well. Analyses 6 and 8 show calcic sodic saline waters. Analysis 1 shows a calcic magnesic alkaline water, and analysis 16 a calcic sodic alkaline water.

Assay 1 of Table 70 represents a test of the city water at Larned and is in accord with analysis 9. Assay 2 is a test of the water of a shallow well in the valley of Pawnee Creek at a point considerably above the flowing salt well. The water is low in carbonates and chlorides, but high in sulphates, though it carries much lower sulphates than are carried by the city water or water of the 25-foot well of the C. W. Smith Electric Light & Ice Co. This 25-foot well (assay 3) and the deep well of the company (assay 4) are both injured by the salt well.

TABLE 70.—*Analyses and assays of underground water from Pawnee County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1902. Oct. 15 | Burdett, surface well | ........ | Atchison, Topeka & Santa Fe Ry. | 8.9 | 2 | 77 | 44 | 23 | 191 | ........ | 68 | 24 | ........ | ........ |
| 2 | ........ | Larned, Frizzell's flowing salt well at edge of Pawnee Creek.[a] | ........ | W. D. Church | 2 | 2.4 | 538 | 73 | 25,291 | 1,883 | ........ | 3,851 | 34,996 | 1.5 | ........ |
| 3 | 1897. Apr. 12 | Larned, Atchison, Topeka & Santa Fe Ry. well. | ........ | Atchison, Topeka & Santa Fe Ry. | 99 | ...... | 149 | 40 | 154 | 187 | ........ | 217 | 236 | 151 | 1,236 |
| 4 | 1899. Feb. 24 | Larned, Davis well on north side of river, 2 miles north of city on SW. ¼ sec. 20. | 20 | ....do | ........ | ...... | 73 | 8.4 | 150 | 159 | ........ | 80 | 137 | 27 | 633 |
| 5 | ...do | Larned, J. W. Rush's well on north side of river one-half mile north of city. | 175 | ....do | ........ | ...... | 40 | 14 | 167 | 105 | ........ | 102 | 169 | 36 | ........ |
| 6 | ...do | Larned, Dickison's well on south side of river, 1½ miles east of city on NW. ¼ sec. 8. | 21 | ....do | ........ | ...... | 141 | 30 | 119 | 87 | ........ | 504 | 47 | 108 | 1,036 |
| 7 | July 22 | Larned, J. W. Athey's old well after pumping 6 days on SE. ¼ sec. 4. | ........ | ....do | ........ | ...... | 183 | 36 | 498 | 164 | ........ | 788 | 421 | 199 | 2,288 |
| 8 | Feb. 24 | Larned, No. 2 well, 1 mile south of city on S. ½ sec. 4. | 20 | ....do | ........ | ...... | 156 | 29 | 90 | 105 | ........ | 444 | 47 | 87 | 962 |
| 9 | 1903. Feb. 19 | Larned, city waterworks well | 25 | ....do | 14 | ...... | 190 | 38 | 121 | 146 | ........ | 568 | 44 | 110 | 1,231 |
| 10 | ...do | Larned, well of Grant Milling Co. | ........ | ....do | 3.4 | ...... | 35 | 13 | 54 | 76 | ........ | 90 | 28 | 53 | 356 |
| 11 | Aug. 29 | Larned, Atchison, Topeka & Santa Fe Ry. surface well after 36 hours pumping. | ........ | ....do | 20 | 1.2 | 68 | 17 | 1,081 | 254 | ........ | 471 | 1,184 | 84 | 3,167 |
| 12 | 1904. July 1 | Larned, Atchison, Topeka & Santa Fe well No. 1, 100 feet west of depot. | 26 | ....do | 17 | ...... | 92 | 20 | 1,269 | 220 | ........ | 654 | 1,429 | 80 | 3,781 |
| 13 | ...do | Larned, Atchison, Topeka & Santa Fe Ry. well No. 1. | 53 | ....do | 17 | ...... | 58 | 14 | 62 | 101 | ........ | 97 | 48 | 32 | 430 |

[a] The deep well at Larned obtained a good flow from the Dakota; it was cased off and the well continued to 750 feet, where a saline flow was obtained (S. Doc. No. 41, pt. 2, pp. 74, 78, 1892).

TABLE 70.—*Analyses and assays of underground water from Pawnee County*—Continued.

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES—continued. | | | | | | | | | | | | | |
| | 1904. | | | | | | | | | | | | | | |
| 14 | July 16 | Larned, Atchison, Topeka & Santa Fe Ry. well No. 1 after 10 hours pumping. | ........ | Atchison, Topeka & Santa Fe Ry. | 10 | ...... | 38 | 16 | 54 | 80 | ......... | 91 | 35 | 89 | 413 |
| 15 | Aug. 12 | Larned, well No. 2, 100 feet east of depot. | 73 | .....do........ | 8.6 | ...... | 42 | 7.9 | 72 | 83 | ......... | 72 | 57 | 22 | 365 |
| 16 | .......... | Larned, well.......... | 50 | Missouri Pacific Ry...... | 24 | 1 | 70 | 12 | 60 | 132 | ......... | 52 | 56 | 11 | 419 |
| | | ASSAYS. | | | | | | | | | | | | | |
| | 1907. | | | | | | | | | | | | | | |
| 1 | Dec. 2 | Larned, city waterworks, 1 well and 3 points. | 25 | .......... | ........ | .0 | ...... | ....... | ......... | .0 | 195 | 624 | 56 | ........ | ........ |
| 2 | ...do..... | Larned, well of Ideal Steam Laundry. | 110 | .......... | ........ | .0 | ...... | ....... | ......... | .0 | 178 | 73 | 30 | ........ | ........ |
| 3 | ...do..... | Larned, well of C. W. Smith Electric Light & Ice Co. | 16 | .......... | ........ | Tr. | ...... | ....... | ......... | .0 | 197 | 157 | 326 | ........ | ........ |
| 4 | ...do..... | .....do.......... | 125 | .......... | ........ | .5 | ...... | ....... | ......... | .0 | 166 | 82 | 120 | ........ | ........ |
| 5 | ...do..... | Larned, Frizzell's flowing salt well at edge of Pawnee Creek. | 841 | .......... | ........ | Tr. | ...... | ....... | ......... | .0 | 211 | 62 | 36,140 | ........ | ........ |

## PHILLIPS COUNTY.

Phillips County lies near the eastern margin of the High Plains, extending from the valley of Prairie Dog Creek southward to and beyond North Fork of Solomon River. The Niobrara formation is extensively exposed in the deeper valleys, and on the higher lands is covered by the late Tertiary sands and grits of the High Plains. The Niobrara is 50 to 200 feet thick in this county and is underlain by the Benton formation 400 feet thick, which, in turn, is underlain by the Dakota sandstone. The formations dip gently to the northeast, the Dakota sandstone ranging in depth from 500 feet in Solomon Valley at the eastern margin of the county to 850 feet in the higher lands to the north and west. The sandstone appears to have been reached at Kirwin, at a depth of 430 feet, by a well which affords a flow, but as the water is from the uppermost beds, or the beds at the base of the Benton, it is too highly mineralized to be of use. A well in Beaver Township, 6 miles south of Cactus, was bored to a depth of 480 feet and found in blue shale a small supply of water which rises within 50 feet of the surface. A few miles northwest of Phillipsburg a similar well is 430 feet deep, and a well in section 21, near Stuttgart, is 398 feet deep. These three wells were, of course, not sufficiently deep to reach the Dakota sandstone.

In 1903 a deep boring was put down 4½ miles northeast of Long Island, in search of oil or gas. At a depth of 650 feet the top of a stratum reported as "hard rock" (probably the Dakota sandstone) was reached. From 50 to 650 feet the boring was in "shale" of the Niobrara and Benton formations, the chalk rock and limestone not being specially recognized. As the altitude of this boring is about 2,050 feet, the altitude of the top of the supposed Dakota sandstone is 1,400 feet.[1]

Erasmus Haworth [2] states that as a number of small areas of Cretaceous rocks are exposed to the surface, the location of wells in the Tertiary has to be judiciously done but that satisfactory supplies are generally obtained wherever the Tertiary mantle is not too thin.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 312.

[2] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 99.

Analysis 1, Table 71, shows a sodic calcic alkaline water. Analysis 2 indicates a calcic alkaline water of considerable temporary hardness, and analysis 5 a water of the same class that is soft. Analyses 3 and 4 denote calcic alkaline saline waters of low temporary and marked permanent hardness. Assays 1, 4, 5, and 6 indicate waters of high temporary and considerable permanent hardness. Assay 2 is a very incomplete test of the water of a deep well which is worthy of further study. Assay 3 shows a highly mineralized water that is probably derived from the gypsiferous and saliferous shales of the Dakota. The well is located on the bluffs south of and 100 feet above Kirwin. The well is cased with 438 feet of $5\frac{5}{8}$-inch steel tubing and 76 feet of $4\frac{1}{2}$-inch kalameined pipe. The well, which at times exhibits a slight flow but usually does not, was put down for stock, but the water proved too salty for their use.

TABLE 71.—*Analyses and assays of underground waters from Phillips County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| | 1909. | | | | | | | | | | | | | | |
| 1 | | Kirwin, dug well | 51 | Missouri Pacific Ry | 22 | 0.6 | 45 | 16 | 79 | 135 | | 98 | 17 | 20 | 433 |
| 2 | | Long Island, well | 32 | Chicago, Burlington & Quincy R. R. | | [a] 72 | 159 | 23 | 39 | 313 | | 22 | 21 | | |
| 3 | | Logan, well | 58 | Missouri Pacific Ry | 17 | 1 | 109 | 26 | 32 | 138 | | 172 | 27 | 49 | 571 |
| 4 | | Phillipsburg, well 3,000 feet from Chicago, Rock Island & Pacific Ry. tank. | 24 | Chicago, Rock Island & Pacific Ry. | | [a] 8 | 112 | 17 | 35 | 189 | | 68 | 28 | | 456 |
| 5 | | Prairie View, well | 60 | do | | [a] 46 | 62 | 11 | 6.5 | 123 | | 15 | 6 | | 270 |
| | | ASSAYS. | | | | | | | | | | | | | |
| | 1907. | | | | | | | | | | | | | | |
| 1 | Sept. 5 | Kirwin, well of Missouri Pacific Ry. Co. | 60 | | | Tr. | | | | .0 | 462 | 88 | 24 | | |
| 2 | do | Kirwin, well of H. W. Kloontz [b] | 375 | | | Tr. | | | | .0 | 144 | | | | |
| 3 | do | Kirwin, well of H. C. Wey on NW. ¼ sec. 3, T. 5 S., R. 16 W. [c] | 514 | | | 1.0 | | | | 59 | 1,248 | ([d]) | 8,500 | | |
| 4 | Oct. 7 | Phillipsburg, old city waterworks well. | 30 | | | .0 | | | | .0 | 338 | Trace. | 36 | | |
| 5 | do | Phillipsburg, new city waterworks well. | 37 | | | .0 | | | | .0 | 363 | 37 | 30 | | |
| 6 | Oct. 8 | Phillipsburg, dug well of Phillipsburg Grain & Elevator Co. | | | | .0 | | | | .0 | 344 | 60 | 52 | | |

[a] $SiO_2+Fe_2O+Al_2O_3$.  [b] Sunk in 1902  [c] Sunk in 1887.  [d] $SO_4$ greater than 626.

## POTTAWATOMIE COUNTY.

Pottawatomie County is underlain by Pennsylvanian series and, in the northwest corner, by an area of Permian beds. The prospect for soft waters is therefore not good unless satisfactory wells should be developed in glacial deposits.

The only waters tested are from wells in the Kansas River valley, so that little is actually known about the ground waters of the county. Both the assay and the analysis in Table 72 represent tests of shallow well waters at Wamego and indicate that the waters have decided permanent and moderate temporary hardness; the chlorides in the two waters are rather high.

TABLE 72.—*Analysis and assay of underground waters from Pottawatomie County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | | |
| 1 | 1908. Mar. 5 | Wamego, 2 wells | 57 | Union Pacific R.R. | 23 | 0.8 | 97 | 13 | 86 | 110 | .... | 156 | 95 | 581 |
| | | ASSAY. | | | | | | | | | | | | |
| 1 | 1907. June 24 | Wamego, city water, 4 wells. | 50 | .................... | ... | .0 | ... | ... | .... | .0 | 292 | 157 | 100 | .... |

## PRATT COUNTY.

Pratt County is situated in south-central Kansas on the High Plains, between Cimarron and Arkansas rivers. Its surface is covered by Tertiary deposits from 50 to 200 feet thick, and its principal water supplies are obtained from coarser sands and gravels at the base of these deposits. The next underlying formation is the Dakota sandstone, which thins out to the south and gives place to "Red Beds," which lie at no great depth in the southeast corner of the county.

The only deep well reported in this county—that at Pratt—is 800 feet deep. Salt was found from 600 feet down. The salt-bearing beds carried some water that rose within 15 feet of the surface. Judging from the experience of the deep well at Anthony, in the adjoining county, the salt-bearing beds are very thick. The underlying limestones are probably not to be reached at a depth of less than 2,500 feet, and possibly much more. Whether these limestones would yield satisfactory water is also uncertain.[1]

Analyses 2, 3, and 5, Table 73, show soft calcic alkaline waters. Analysis 1 is a test of a soft calcic sodic alkaline water, and analysis 4 of a hard calcic saline water. The three water assays indicate soft waters.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 312.

TABLE 73.—*Analyses and assays of underground waters from Pratt County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1902. Dec. 8 | Pratt, wells | ........ | Chicago, Rock Island & Pacific Ry. | 20 | 1.4 | 38 | 3.7 | 42 | 79 | ........ | 11 | ........ | 41 | ........ | ........ |
| 2 | 1908. Sept. | Pratt, well | 110 | do | ........ | a 18 | 55 | 6.6 | 18 | 73 | ........ | 14 | ........ | 35 | ........ | 219 |
| 3 | 1901. May 24 | Sawyer, well | ........ | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 58 | ........ | 17 | 85 | ........ | 12 | ........ | 20 | 17 | 209 |
| 4 | do | do | ........ | do | ........ | ........ | 114 | 43 | 13 | 97 | ........ | 132 | ........ | 141 | 17 | 558 |
| 5 | 1902. Oct. 21 | Sawyer, surface well | ........ | do | 25 | 1.2 | 57 | 5 | 11 | 95 | ........ | 12 | ........ | 12 | ........ | ........ |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | 1907. Nov. 7 | Pratt, city waterworks, 15 points. | 55 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 185 | Trace. | ........ | 94 | ........ | ........ |
| 2 | do | Pratt, well of Pratt Light & Ice Co. | 90 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 172 | Trace. | ........ | 26 | ........ | ........ |
| 3 | do | Pratt, well of Chicago, Rock Island & Pacific Ry. | 100 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 161 | Trace. | ........ | 30 | ........ | ........ |

a $SiO_2+Fe_2O_3+Al_2O_3$.

## RAWLINS COUNTY.

Rawlins County lies on the High Plains and is traversed by the valleys of Beaver and Sappa creeks. The entire area appears to be covered by Tertiary beds, except in the .bottoms of some valleys, where the underlying Pierre shale is revealed. The Pierre formation is several hundred feet thick, the State well at McDonald having penetrated it for 213 feet without reaching its base. The underlying Niobrara formation and the Benton group have a thickness of about 900 feet. The Dakota sandstone is at an altitude of 850 to 1,150 feet above sea level. It dips gently to the northwest, and should therefore be expected at a depth of 1,600 feet in the southeast corner of the county and at 2,400 feet on the higher lands of the western tier of townships. Judging from the experience of the wells in the adjoining county—Decatur—the formation contains water, but not under sufficient head to yield a flow even in the deeper valleys.[1]

Still farther west in Decatur and Rawlins counties the Cretaceous deposits are relatively thick and the wells are correspondingly deep, but in almost every case the supply of water is abundant and the quality good. Some of the tributaries of the Republican in Rawlins County have cut their channels downward through the Tertiary, and for some distance into the Cretaceous, giving areas where the water supply is deficient. But while this result has been produced, another one exceedingly advantageous has also been brought about. The streams cutting through the Tertiary to the Cretaceous floor have made it possible for springs to exist. It is by no means uncommon in Rawlins and Cheyenne counties, particularly in the latter, to find various valleys along the principal tributaries of the Republican which are well watered the year round without any artificial application. The valleys have been corroded to the base of the Tertiary and an outlet to the general body of underground water has been produced, so that constant seepage is in progress, forming pools of living water here and there along the streams, and frequently saturating the soil of the valleys to so great an extent that even in dry seasons further application of water is not desirable.[2]

Both the analyses and assays presented in Table 74 represent tests of waters in the valley of Beaver Creek. The assays should be compared with assay 1, Decatur County (Table 20). Analysis 1 denotes a calcic magnesic alkaline water, analysis 2 shows calcic sodic alkaline water, and analysis 3 a sodic calcic alkaline water. Of these analyses Nos. 1 and 2 show waters of high temporary and noticeable permanent hardness; analysis 3 indicates a soft water. The assays represent waters of high temporary and permanent hardness.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 313.

[2] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas p. 99.

TABLE 74.—*Analyses and assays of underground waters from Rawlins County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | |
| | 1909. | | | | | | | | | | | |
| 1 | .......... | Blakeman, well | 50 | Chicago, Burlington & Quincy R. R. | *a* 62 | 133 | 43 | 76 | 321 | .... | 80 | 40 |
| 2 | .......... | Herndon, well | 20 | ....do | *a* 52 | 121 | 25 | 99 | 310 | .... | 54 | 33 |
| 3 | .......... | McDonald, well | 210 | ....do | *a* 89 | 59 | 17 | 74 | 182 | .... | 46 | 19 |
| | | ASSAYS. | | | | | | | | | | |
| | 1907. | | | | | | | | | | | |
| 1 | Oct. 2 | Atwood, city waterworks, 3 wells. | 32-36 | .................... | .0 | .... | ... | .... | .0 | 323 | 66 | 26 |
| 2 | ...do.... | Atwood, public well at Fourth and State Streets. | ...... | .................... | .0 | .... | ... | .... | .0 | 323 | 198 | 36 |

*a* $SiO_2+Fe_2O_3+Al_2O_3$.

## RENO COUNTY.

The northeastern part of Reno County and a considerable area in the southern part are underlain by Permian beds. Except for an area in the northwestern part, where the Dakota sandstone is the underlying formation, the rest of the county is covered with Tertiary deposits.

Analyses 1, 2, 13, 14, 15, and 16 (Table 75) represent tests of waters from wells in the drainage basin of North Fork of Ninnescah River. All of these waters, except that from the well at Sylvia, are high in chlorides and it may be that this is characteristic of wells in the basin of the North Fork. Those waters of which analyses 1, 2, and 13 are tests are more highly mineralized than those whose quality is indicated by analyses 14, 15, and 16. Analysis 12 shows a water high in sodium and chlorides, which perhaps come from the solution of common salt, for there were salt works operated at Nickerson from 1888 to 1891. The rest of the group of analyses are tests of shallow well waters in Hutchinson. The high calcium, sulphates, and chlorides seem to point to the fact that the salt and possibly ice industries have contaminated this class of wells. This seems particularly evident in the waters whose quality is indicated by analyses 4, 8, and 11. Analyses 3, 6, and 10 give some evidence that the waters of which they are tests are not unaffected by the operations of these manufactures. Analyses 7 and 9 show the composition of waters that probably approach the normal for the region.

The assays suggest the same inference as to the contamination of the shallow wells by the salt and possibly the ice industries. The wells of which 1 and 2 are assays are in the northern part of Hutchinson away from the influence of the wastage of the salt and ice factories, whereas the other wells are in the southern part of the city and do not escape it. The points in Cow Creek are below salt works; the Dairy Company well is not far from them and the two other wells are in the southeastern part of the city near Arkansas River, toward which the subsurface drainage makes.

TABLE 75.—*Analyses and assays of underground waters from Reno County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | | |
| 1 | 1902. Oct. 21 | Abbyville, surface well | ........ | Atchison, Topeka & Santa Fe Ry. | 22 | 2.5 | 105 | 7.6 | 98 | 176 | ........ | 24 | ........ | 133 | ........ | ........ |
| 2 | 1908. Sept. | Arlington, well | 20 | Chicago, Rock Island & Pacific Ry. | ........ | a12 | 96 | 12 | b 40 | 98 | ........ | 42 | ........ | c 121 | ........ | 421 |
| 3 | 1902. Dec. 10 | Hutchinson, wells of Hutchinson Water & Light Co. | 40–60 | Kennicott Water Softener Co. | 16 | 2.4 | 80 | 35 | 73 | 94 | ........ | 154 | ........ | 129 | ........ | ........ |
| 4 | 1897. Apr. 3 | Hutchinson, Atchison, Topeka & Santa Fe Ry. well. | 40–60 | Atchison, Topeka & Santa Fe Ry. | 17 | ...... | 94 | 17 | 152 | 124 | ........ | 96 | ........ | 233 | 41 | 772 |
| 5 | 1906. Nov. 17 | Hutchinson, 16 wells of Hutchinson Water & Light Co. | 40–60 | F. W. Bushong | 17 | c.2 | 85 | 14 | 100 | .0 | 279 | 125 | 0.45 | 130 | ........ | 610 |
| 6 | 1902. Oct. 22 | Hutchinson, surface well | 40–60 | Atchison, Topeka & Santa Fe Ry. | 14 | ...... | 76 | 13 | 102 | 106 | ........ | 124 | ........ | 115 | ........ | ........ |
| 7 | 1904. Mar. 15 | Hutchinson, well of Kansas Grain Co. | 71 | .....do | 17 | 1.2 | 64 | 15 | 94 | 119 | ........ | 74 | ........ | 105 | 34 | 526 |
| 8 | ........ | Hutchinson, well of Hutchinson Ice Co. | ........ | Kennicott Water Softener Co. | 16 | ...... | 180 | 30 | 411 | 142 | ........ | 194 | ........ | 733 | ........ | ........ |
| 9 | 1905. Jan. 24 | Hutchinson, well of the Carey Salt Co., 45 feet southwest of the company's dump. | 20 | .....do | 14 | .7 | 80 | 14 | 84 | 136 | ........ | 61 | ........ | 109 | ........ | ........ |
| 10 | May 17 | Hutchinson, well of the Carey Salt Co., 100 feet north of the company's dump. | 20 | .....do | 11 | 1 | 112 | 17 | 121 | 138 | ........ | 170 | ........ | 146 | ........ | ........ |
| 11 | Aug. 31 | Hutchinson, well of Carey Salt Co., in alley 140 feet north of the company's dump. | 20 | .....do | 16 | .7 | 145 | 22 | 159 | 138 | ........ | 197 | ........ | 255 | ........ | ........ |

a $SiO_2+Fe_2O_3+Al_2O_3$.  b Calculated.  c Al=28.

TABLE 75.—*Analyses and assays of underground waters from Reno County*—Continued.

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES—continued. | | | | | | | | | | | | | | |
| 12 | 1897. Apr. 5 | Nickerson, Atchison, Topeka & Santa Fe Ry. well. | ........ | Atchison, Topeka & Santa Fe Ry. | 17 | ...... | 138 | 15 | 264 | 215 | ......... | 45 | ........ | 407 | 58 | 1,159 |
| 13 | .......... | Olcott, well | 12 | Missouri Pacific Ry... | 21 | 1.5 | 101 | 14 | 99 | 152 | ......... | 81 | ........ | 131 | 33 | 634 |
| 14 | 1902. Nov. 22 | Sylvia, surface well | ........ | Atchison, Topeka & Santa Fe Ry. | 20 | ...... | 46 | 3.6 | 29 | 76 | ......... | 17 | ........ | 33 | ........ | ........ |
| 15 | Dec. 8 | Turon, well | ........ | Chicago, Rock Island & Pacific Ry. | 19 | 2 | 63 | 4.1 | 100 | 104 | ......... | 29 | ........ | 132 | ........ | ........ |
| 16 | 1908. Sept. | .....do | 48 | .....do | ........ | a12 | 79 | 11 | 100 | 138 | ......... | 32 | ........ | 139 | ........ | 511 |
| | | ASSAYS. | | | | | | | | | | | | | | |
| 1 | 1906. Nov. 19 | Hutchinson, well 124 West Second Street. | 55 | .......... | ........ | .2 | ........ | ........ | .......... | .0 | 241 | 50 | ........ | 90 | ........ | ........ |
| 2 | ...do.... | Hutchinson, well of Kansas Grain Co., 112 West Second Street. | 71 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 241 | 62 | ........ | 101 | ........ | ........ |
| 3 | 1907. Aug. 9 | Hutchinson, points of Union Ice Co., in bed of Cow Creek, three-fourths block north of C Street on Poplar Street.[b] | 55 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 258 | 197 | ........ | 3,748 | ........ | ........ |
| 4 | Nov. 19 | Hutchinson, well of Swift Dairy Co., F and Main Streets. | 45 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 224 | 287 | ........ | 291 | ........ | ........ |
| 5 | ...do.... | Hutchinson, well, 204 Carpenter Street. | 38(?) | .......... | ........ | 1.8 | ........ | ........ | .......... | .0 | 212 | 460 | ........ | 492 | ........ | ........ |
| 6 | ...do.... | Hutchinson, well, 127 Park Street. | 28 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 202 | 530 | ........ | 446 | ........ | ........ |

a $SiO_2+Fe_2O_3+Al_2O_3$.

b Used in the manufacture of ice and in boilers.

## REPUBLIC COUNTY.

Republic County, which comprises a portion of Republican Valley and the highlands eastward, is mainly on the eastern edge of the Benton shales, with the Dakota sandstone exposed in Republican Valley. The formations are nearly level or dip very gently to the northwest.

A number of wells have been bored through the Benton shales into the Dakota sandstone, and others are sunk in the sandstone itself, most of these wells obtaining satisfactory water. At Belleville a city supply is obtained from wells 155 feet deep, sunk through Benton shales into Dakota sandstone; the wells yield 25 gallons a minute. The only deep boring reported in the county, that at Scandia, reached a depth of 1,110 feet, passed through the Dakota sandstone into Permian rocks, and at a depth of 1,000 feet found excellent water, which rose within 16 feet of the surface[a].

Analysis 1, Table 76, denotes a calcic magnesic alkaline water that is not very highly mineralized. Analyses 2 and 3 show hard calcic alkaline waters, and analysis 4 indicates a sodic calcic alkaline water.

Assay No. 1 is a test of the city water from the Dakota sandstone. The sulphate and bicarbonate figures both are high and mark the water as having high permanent and temporary hardness. The assay of the shallow well water at Scandia shows the water to be hard.

TABLE 76.—*Analyses and assays of underground waters from Republic County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1908. Sept. | Narka, well, 900 feet from tank. | 35 | Chicago, Rock Island & Pacific Ry. | ... | [b] 1.9 | 43 | 21 | 10 | 106 | .... | 22 | 11 | .... | 215 |
| 2 | ...do..... | Scandia, well, 100 feet from tank. | 28 | .....do............. | ... | [b] 7.9 | 86 | 15 | 42 | 148 | .... | 65 | 39 | .... | 403 |
| 3 | .......... | .....do............... | 16 | Missouri Pacific Ry. | 33 | .8 | 118 | 14 | 65 | 203 | .... | 101 | 43 | 66 | 645 |
| 4 | 1909. | Wayne, well....... | 60 | Chicago, Burlington & Quincy R. R. | ... | [b]31 | 195 | 22 | 268 | 384 | .... | 195 | 227 | .... | .... |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Feb. 21 | Belleville, city waterworks well. | 154 | .................. | ... | 2.5 | ... | ... | .... | .0 | 436 | 91 | 44 | .... | .... |
| 2 | Feb. 22 | Scandia, well in Miller's livery stable. | 16 | .................. | ... | Tr. | ... | ... | .... | .0 | 382 | 67 | 24 | .... | .... |

[a] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 313.
[b] $SiO_2 + Fe_2O_3 + Al_2O_3$.

## RICE COUNTY.

Rice County includes a small portion of Arkansas Valley below the Great Bend and extends northward to the low divide toward Smoky Hill Valley. The greater part of the county is underlain by Dakota sandstone, but the underlying Permian beds appear to the southeast.

Many shallow wells obtain water from the Dakota sandstone. There are a number of salt wells and shafts in the county, one boring at Lyons having been carried to a depth of 1,625 feet.

In Sterling there are brine wells 916 and 946 feet deep, and at Little River a salt well 1,000 feet deep was reported. The thickness of the salt-bearing formations and the nature of the rocks by which they are underlain have not been determined.[1]

Analysis No. 1, Table 77, shows a soft calcic alkaline water. Analysis 2 and assay 7 show the composition of a water from the Dakota sandstone. The sandstone is entered at 45 feet and passed through at 50 feet. The well yields 45 gallons a minute and the water rises to within 30 feet of the surface. The water is soft and contains a considerable amount of chlorides. Analyses 3, 4, and 5 show hard calcic alkaline waters; analysis 6 indicates a very hard calcic alkaline water high in chlorides.

A clay stratum is locally believed to separate the two sets of wells, of which 1 and 2 are assays. In some parts of Sterling this clay stratum is not found by wells which are sunk deep enough to pierce it, so that it is not unlikely that the wells are all connected with each other. The sample of which No. 1 is an assay was taken after 5,500 gallons of water had been pumped. The four wells were then disconnected and the pumps attached to the two 48-foot wells from which a like quantity of water was pumped before the sample, of which No. 2 is an assay, was taken. Assay 2 shows lower sulphates and higher chlorides than are shown by 1. As these two sets of wells tap the underflow of Arkansas River the lower sulphates in the deeper sample is to be expected, but the higher chlorides is not easily explained. Assay 3 is a test of another shallow well water in the Arkansas River underflow. Assay 4 shows the composition of the water of the well at the Sterling salt works that was put down in 1902 and in 1907 was abandoned for boiler use because the infiltration of salt had destroyed it. Assay 5 is a test of the water of the well that was sunk in March, 1907, to be used in place of the old well. Assay 6 is a test of the city water of Lyons, which is shown to have considerable temporary and but little permanent hardness.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 313.

TABLE 77.—*Analyses and assays of underground waters from Rice County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | .......... | Bushton, 2 wells | 108 | Missouri Pacific Ry. | 24 | 1 | 82 | 9 | 13 | 142 | .......... | 14 | 14 | 5 | 304 |
| 2 | 1900. Jan. 20 | Lyons, well No. 1 of Bevis Rock Salt Co.[a] | 60 | Chauvinet & Bro. | ........ | ........ | 120 | 7.8 | 96 | 199 | .......... | ........ | 147 | ........ | 604 |
| 3 | ...do..... | Lyons, well of Mr. Ahlberg, half mile north of Bevis Rock Salt Co.[b] | 30 | .....do | ........ | ........ | 110 | 3.5 | 36 | 174 | .......... | 56 | ........ | ........ | 379 |
| 4 | 1902 Sept. 19 | Lyons, well | ........ | Atchison, Topeka & Santa Fe Ry. | 28 | 1.2 | 85 | 14 | 50 | 146 | .......... | 46 | 60 | ........ | ........ |
| 5 | 1903. Aug. 26 | Lyons, well of Atchison, Topeka & Santa Fe Ry. | ........ | .....do | 15 | ........ | 78 | 8.8 | 32 | 106 | .......... | 39 | 60 | 199 | 538 |
| 6 | ...do..... | Lyons, city water, wells | 53 | .....do | 34 | 3.5 | 158 | 12 | 38 | 176 | .......... | 46 | 133 | 31 | 633 |
| 7 | 1902. Aug. 22 | Sterling, surface well | ........ | .....do | 15 | 4.4 | 101 | 37 | 126 | 163 | .......... | 147 | 178 | ........ | ........ |
| | | ASSAYS. | | | | | | | | | | | | | |
| 1 | 1907. Oct. 26 | Sterling, city waterworks, 4 wells | 30 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 295 | 99 | 172 | ........ | ........ |
| 2 | ...do.... | Sterling, city waterworks, 2 wells | 48 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 300 | 74 | 203 | ........ | ........ |
| 3 | Oct. 27 | Sterling, well of Sterling Ice & Produce Co. | 25 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 332 | 208 | 216 | ........ | ........ |
| 4 | ...do..... | Sterling, well in pump room of Sterling Salt Works.[c] | 54 | .......... | ........ | Trace. | ........ | ........ | .......... | .0 | 343 | 245 | 3,382 | ........ | ........ |
| 5 | ...do..... | Sterling, well 215 feet north of plant of Sterling Salt Works.[d] | 50 | .......... | ........ | Trace. | ........ | ........ | .......... | .0 | 300 | 92 | 227 | ........ | ........ |
| 6 | Oct. 28 | Lyons, city waterworks, 17 wells | 53 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 323 | Trace. | 135 | ........ | ........ |
| 7 | ...do..... | Lyons, well of Bevis Rock Salt Co.[e] | 60 | .......... | ........ | .0 | ........ | ........ | .......... | .0 | 285 | Trace. | 114 | ........ | ........ |

[a] Analysis furnished by Jesse Ainsworth. Well is in the Dakota sandstone.
[b] Analysis furnished by Jesse Ainsworth.
[c] Put down in 1902 and abandoned for boiler use in 1907, owing to infiltration of salt.
[d] Put down in March, 1907.
[e] From Dakota sandstone.

## RILEY COUNTY.

Riley County is underlain by Permian beds, except in the eastern and southeastern parts where Big Blue River and its tributaries have cut through to the Pennsylvanian series. The prospect for soft waters is not bright, for both the Permian and Pennsylvanian series yield hard waters.

Analysis 1, Table 78, shows a water of high temporary and slight permanent hardness. Analysis 2 indicates a calcic alkaline water of high temporary and considerable permanent hardness. The four city wells are located at the base of a high bluff, and it is locally believed that they are supplied by sheet water from beneath the bluff. Analysis 3 indicates a very hard water. Analysis 4 is a test of a very hard and probably corrosive calcic magnesic saline water.

Assays 1 to 10 were made in the course of an investigation of the wells in the city of Manhattan. The citizens call some of the well waters hard and others soft. To determine whether there was actually any difference in the waters, tests were made of wells located in widely separated parts of the city. It was found that the wells whose waters had a high permanent hardness were called hard and the others soft, though the temporary hardness of all of the wells is very marked. The wells of high permanent hardness are the ones of which assays 2, 3, 6, and 10 are tests. All of these wells are located in the southeastern part of the city in an area bounded by Big Blue River, El Paso, Fourth, and Fremont streets.

Assay 11 indicates a water of very high temporary and moderate permanent hardness.

TABLE 78.—*Analyses and assays of underground waters from Riley County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | 1902. Dec. 10 | Manhattan, Chicago, Rock Island & Pacific Ry. well. | ........ | Kennicott Water Softener Co. | 26 | 13 | 90 | 21 | 54 | 214 | ........ | 33 | 26 | ........ |
| 2 | 1908. Sept. | Manhattan, city waterworks, 4 wells... | 37 | Chicago, Rock Island & Pacific Ry. | ........ | $^a$8 | 120 | 26 | 28 | 234 | ........ | 47 | 20 | 483 |
| 3 | 1902. Dec. 16 | Riley, Chicago, Rock Island & Pacific Ry. well. | 23 | Kennicott Water Softener Co. | 23 | 4.2 | 268 | 78 | ........ | 158 | ........ | 662 | 29 | ........ |
| 4 | 1908. Sept. | Riley, well 50 feet from Chicago, Rock Island & Pacific Ry. tank. | 97 | Chicago, Rock Island & Pacific Ry. | ........ | $^a$4.3 | 316 | 102 | 57 | 66 | ........ | 1,143 | 22 | 1,710 |
| | | ASSAYS. | | | | | | | | | | | | |
| 1 | 1907. Feb. 13 | Manhattan, city supply, 4 wells........ | 37 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 483 | Trace. | 24 | ........ |
| 2 | ...do..... | Manhattan, well of Manhattan Light & Power Co. | 46 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 302 | 78 | 90 | ........ |
| 3 | ...do..... | Manhattan, well, Second and Colorado Streets. | ........ | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 344 | 215 | 80 | ........ |
| 4 | ...do..... | Manhattan, well, 1015 Pierre Street..... | 36 | ........ | ........ | 3.5 | ........ | ........ | ........ | .0 | 465 | Trace. | 40 | ........ |
| 5 | ...do..... | Manhattan, well, Fourteenth and Houston Streets. | 60 | ........ | ........ | 1.0 | ........ | ........ | ........ | .0 | 410 | Trace. | 30 | ........ |
| 6 | ...do..... | Manhattan, well, 212 Poyntz Street.... | 62 | ........ | ........ | 1.0 | ........ | ........ | ........ | .0 | 268 | 119 | 151 | ........ |
| 7 | ...do..... | Manhattan, well, 223 Poyntz Street.... | 35 | ........ | ........ | Trace. | ........ | ........ | ........ | .0 | 297 | ........ | 151 | ........ |
| 8 | ...do..... | Manhattan, well, 810 Fremont Street... | ........ | ........ | ........ | 5.0 | ........ | ........ | ........ | .0 | 418 | Trace. | 20 | ........ |
| 9 | ...do..... | Manhattan, well, Seventh and Moro Streets. | 32 | ........ | ........ | 2.0 | ........ | ........ | ........ | .0 | 434 | Trace. | 24 | ........ |
| 10 | ...do..... | Manhattan, well, 331 Osage Street...... | ........ | ........ | ........ | 9.0 | ........ | ........ | ........ | .0 | 345 | 173 | 115 | ........ |
| 11 | Feb. 14 | Randolph, well at Union Pacific R. R. depot. | 20 | ........ | ........ | .0 | ........ | ........ | ........ | .0 | 410 | 44 | 14 | ........ |

$^a$ $SiO_2+Fe_2O_3+Al_2O_3$.

ROOKS COUNTY.

Rooks County comprises a portion of the Solomon River valley and the adjoining ridges of high plains. The whole county appears to be underlain by the Niobrara formation, covered on the higher lands by Tertiary deposits. The Dakota sandstone lies more than 500 feet below the surface on the highest lands and at a depth somewhat less in the valleys, especially above North Fork of Solomon River below Stockton. The strata dip gently to the north.

The Dakota sandstone will not afford surface flows in this county, except possibly in the bottoms of some of the deeper valleys. The deepest well reported (490 feet deep) passes through the lower beds of the Niobrara and the Benton formations to the Dakota sandstone. It is situated on the slopes 9 miles south of Stockton, on the road to Plainville, and yields a large supply of excellent water, which rises to within 60 feet of the surface.[1]

A good illustration of the perplexing conditions that are sometimes encountered in locating wells in the Tertiary is afforded in Stockton. Here the valley of North Fork of Solomon River has been cut down into Niobrara chalk for 100 feet or more. Subsequently, a filling-in process occurred until the valley was filled to a depth of from 30 to 50 feet, producing a broad level surface over which the river flows as it now exists. Well drilling on the different lots in Stockton yields varying results. In one part of the town water can be found in great abundance. In another part, however, water is not found, but in its stead the chalk is reached at a depth less than that at which water is found on adjoining lots. The explanation is easily understood. An underground ridge of the chalk beds extends outward into the valley some distance, a ridge similar to that which we often see along valleys at the present time. The old Solomon River valley is filled with water to a certain level. A well drilled in it at any point where the water level covers the chalk bed floor will find an abundance of water. But should the drill be started over one of these chalk ridges which extends down into the valley, so that the surface of the chalk is higher than the underground water level, of course no water could be found.[2]

The only analysis presented in Table 79 is of the water of the city of Stockton, which draws its supply from six points sunk 10 feet in the bottom of a well 40 feet deep that is 800 feet northeast of North Fork of Solomon River. The water is shown by the analysis and by assay 2 to be very hard. Assay 3 shows a somewhat harder water. Assay 4 is the test of a moderately hard shallow well water in the valley of Robbers Roost Creek. Assay 5 indicates that the water which is from a shallow well is very hard. Assays 6 and 7 are tests of waters from wells that are known to reach the Dakota sandstone and the high degree of mineralization of the waters indicates that they are derived from the saliferous and gypsiferous shales of that formation. Probably if the wells were sunk deeper into the

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 314.

[2] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 61.

rock, softer water would be obtained. Assay 1 is a test of a well in the Saline River valley and is a very much softer water than any of the other waters of the county that were assayed.

TABLE 79.—*Analysis and assays of underground waters from Rooks County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | | |
| 1 | ........ | Stockton, 6 points, city waterworks. | 50 | Missouri Pacific Ry. | 38 | 1.4 | 108 | 9.9 | 64 | 161 | 154 | 15 | 16 | 569 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1907. | | | | | | | |
| 1 | Sept. 9 | Plainville, well of Hotel Bales........ | 52 | 0.0 | 0.0 | 275 | Trace. | 34 |
| 2 | Sept. 8 | Stockton, city waterworks, from points.................................. | 60 | 1.5 | .0 | 344 | 138 | 19 |
| 3 | ...do..... | Stockton, well of W. O. Cross......... | 23 | .0 | .0 | 323 | 202 | 39 |
| 4 | ...do..... | Stockton, well of W. T. Anderson, on sec. 1, T. 8 S., R. 18 W............. | ........ | .0 | .0 | 312 | 44 | 19 |
| 5 | ...do..... | Stockton, dug well of O. Hazen, NE. ¼ sec. 35, T. 8 S., R. 18 W........... | 80 | Trace. | .0 | 380 | 186 | 19 |
| 6 | ...do..... | Stockton, well of O. Hazen, NE. ¼ sec. 35, T. 8 S., R. 18 W.[a]........... | 475 | Trace. | .0 | 635 | 431 | 1,833 |
| 7 | ...do..... | Stockton, well of O. Hazen, sec. 35, T. 8, R. 18 W.[b]...................... | 504 | .0 | 63 | 658 | 626 | 1,635 |

[a] Sunk in 1903. [b] Taken from tank.

## RUSH COUNTY.

Over most of Rush County the surface formation is Benton shale, but the Dakota sandstone is said to appear in its southeastern corner. The beds dip gradually to the north, so that along the northern border of the county the depth to the sandstone is 200 to 500 feet, the latter being the elevation of the highest land in the divide south of Smoky Hill River. The sandstone has been reached by a number of wells which usually yield satisfactory supplies of excellent water. At Lacrosse and in its vicinity there are many wells from 300 to 400 feet deep. At Otis a well 260 feet deep is reported. In the higher lands northeast of Lacrosse a plentiful supply of soft water, which rises to within 240 feet of the surface, is found in the sandstone at a depth of 444 feet. In the township south of Lacrosse some wells find the Dakota sandstone waters slightly too saline to be palatable for domestic use. In other portions of the county salty waters are found in some wells which stop in the first sandstone layers under the Benton shale, a horizon which usually yields unsatisfactory waters. By deepening these wells a few feet the Dakota sandstone should be penetrated and probably more satisfactory water obtained. No reports have been received of wells sunk into the formations underlying the Dakota sandstone. It is to be expected that such wells, unless very deep, would find nothing but the salty water of the Red Beds.[1]

The fluviatile deposits in the valleys of the Walnut and its tributaries are of great importance as furnishing the principal water supply of this area [Walnut Creek valley]. The valley of the Walnut is filled in with sands and clays, having a substratum of gravel for a considerable width. The important tributaries of this stream on the south are Dry Walnut, Otter Creek, and Old Maids Fork; on the north Sand Creek, Alexander Dry Creek, Bazine Dry Creek, and Long's Branch. These likewise have their valleys filled in with considerable deposits of fluviatile material.

* * * * * * *

Under this last head [water in the Tertiary] may be included only a few wells found on the high divide between the Pawnee and the Walnut. The Tertiary here is found in only a few irregular patches and usually is not of great enough extent to form a reservoir capable of supplying a large amount of water. There are many wells, however, which depend upon it for their supply.[2]

Under the head of the fluviatile, the water supply of the city of Lacrosse should be mentioned. Here we have a town located on a small stream, with the water found in the underflow of its immediate valley, which extends in a comparatively narrow zone through the city. Wells dug on either side of this extend into the Benton and fail to find water.

Analysis 1, Table 80, shows a sodic saline water from the Dakota sandstone. Analysis No. 2 is the test of a mixture of water from a shallow and a deep well. Assays 1 and 2 show the quality of water in each of these wells. Both are high in sulphates, chlorides, and bicarbonates. Analysis 3 shows a very hard sodic calcic saline water from the fluviatile deposits of Walnut Creek.

All of the assays, except the first, are tests of wells which derive their water from the Dakota sandstone. The waters are very hard and the high sulphates and chlorides indicate that the waters come from the gypsiferous and saliferous shales at the top of the Dakota. Probably more satisfactory waters could be obtained by sinking the wells deeper.

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 314–315.

[2] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, pp. 107, 108.

Table 80.—*Analyses and assays of underground waters from Rush County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | ............. | Bison, well........ | 294 | Missouri Pacific Ry. | 24 | 2.7 | 40 | 12 | 241 | 118 | 66 | 287 | 9.9 | 802 |
| 2 | ............. | Lacrosse, 2 wells. | 300<br>36 | ...do.............. | 19 | 3 | 22 | 5.6 | 431 | 131 | 223 | 400 | 5.5 | 1,242 |
| 3 | 1902.<br>Dec. 15 ..... | Rush Center, surface well. | ... | Atchison, Topeka & Santa Fe Ry. | 28 | 1.2 | 196 | 21 | 244 | 153 | 264 | 408 | .... | ..... |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1907.<br>Dec. 16 | Lacrosse, dug well of Missouri Pacific Ry ........ | 36 | Trace. | 0.0 | 229 | 276 | 146 |
| 2 | ...do..... | Lacrosse, well of Missouri Pacific Ry.............. | 300 | 0.0 | .0 | 267 | 237 | 453 |
| 3 | ...do..... | Lacrosse, well of Bert Shiney..................... | 234 | .0 | .0 | 280 | 265 | 443 |
| 4 | ...do..... | Lacrosse, well of John Montfort.................. | 210 | .0 | 21 | 279 | 344 | 490 |
| 5 | ...do..... | Lacrosse, well of W. H. Russell, SW. ¼ sec. 3, T. 18 S., R. 18 W ............................ | 295 | .0 | .0 | 280 | 265 | 443 |
| 6 | ...do..... | Lacrosse, well of Judge Anderson, NE. ¼ sec. 9, T. 18 S., R. 18 W ............................ | 308 | .0 | .0 | 272 | 237 | 457 |
| 7 | ...do..... | Lacrosse, well of Jas. A. Hite, SW. ¼ sec. 27, T. 17 S., R. 18 W .................................... | 325 | Trace. | .0 | 317 | 208 | 438 |

## RUSSELL COUNTY.

Russell County comprises portions of the valleys of Smoky Hill and Saline rivers and adjoining divides. Over the greater part of the county the Benton shales lie at the surface, Dakota sandstone being exposed to the east in the valleys of the two rivers. The formation dips very gently to the north and is nowhere more than 500 feet below the surface, the depth being least along the river bottoms in the east, central, and south portions of the county. Many wells reach this sandstone and obtain water supplies, usually of good quality and in considerable volume. One well in Saline River bottom, northwest of Russell, is 125 feet deep and obtains from the Dakota sandstone a flow of moderately hard water, which is said to have sufficient pressure to rise 40 feet above the mouth of the well. Some of the wells obtain their water from the top sandstone of the Dakota, and others go deeper into the formation to obtain better supplies. A well at Russell 325 feet deep apparently did not reach the Dakota sandstone, but another well at this place, sunk to a depth of 997 feet, obtained water, which rose to within 300 feet of the surface but was too salty for use. A flow of fresh water was reported at 360 feet, apparently from Dakota sandstone, and it is claimed that rock salt was penetrated. This well was mainly in the Permian shales.[a]

Analysis 1, Table 81, shows a hard calcic alkaline water. Analysis 2 exhibits a highly mineralized water from the Dakota sandstone. Analysis 3 is a test of a calcic sodic saline water.

The most satisfactory water shown by the assays is that of the spring that supplies Bunker Hill. The water has decided permanent hardness, but otherwise is very acceptable. Assay 2 denotes the softest water of the series of assays. Assays 3 and 4 are tests of waters of wells in the Dakota sandstone and indicate by the high sulphates and chlorides that these waters are derived from the gypsiferous and saliferous shales at the top of the formation. Assay 5 shows the quality of water of a shallow well in the valley of Wolf Creek, a tributary of Saline River, to be very hard. Assay 6 indicates the quality of the average shallow well of Russell, where the problem of obtaining good soft water has not been solved. Assay 7 is a test of a very hard water from a spring situated at the edge of Saline River and which it has been proposed to pipe into Russell for a public supply.

TABLE 81.—*Analyses and assays of underground waters from Russell County.*

[Parts per million.]

| No. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ANALYSES. | | | | | | | | | | | |
| 1 | Dorrance, well 300 feet east of station of Union Pacific R. R. | 60 | Union Pacific R.R. | 17 | 1.4 | 108 | 0.0 | 32 | 136 | 76 | 22 | 392 |
| 2 | Fay, flowing well[b] of Mr. Kellogg, SE. ¼ sec. 14, T. 12 S., R. 15 W. | 121 | J. T. Willard | ... | ... | 171 | 282 | (Na) 4,921 (K) 39 | 405 | 2,066 | 6,742 | 14,627 |
| 3 | Gorham, well | 43 | Union Pacific R.R. | 18 | 7.7 | 124 | 11 | 94 | 133 | 214 | 84 | 689 |

[a] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 315.

[b] Derived from Dakota sandstone.

TABLE 81.—*Analyses and assays of underground waters from Russell County*—Continued.

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1907. | | | | | | | |
| 1 | Sept. 17 | Bunker Hill, city supply spring from sandstone 2½ miles south of city, sec. 18, T. 14 S., R. 13 W | ........ | 0.0 | 0.0 | 300 | 77 | 44 |
| 2 | ...do.... | Bunker Hill, well of C. E. Lindsay, sec. 14, T. 6 S., R. 12 W. [a] | 23 | .0 | .0 | 445 | Tr | 29 |
| 3 | ...do..... | Buuker Hill, well of C. E. Lindsay, sec. 14, T. 6 S., R. 12 W. [b] | 246 | Tr. | .0 | 312 | 150 | 260 |
| 4 | ...do..... | Bunker Hill, well of A. H. Shaffer [c] | 265 | Tr. | .0 | 462 | 406 | 1,637 |
| 5 | Sept. 9 | Lucas, city waterworks well | 50 | .0 | .0 | 386 | 108 | 280 |
| | 1908. | | | | | | | |
| 6 | Sept. 18 | Russell, well at livery stable of D. C. Winfield | 25 | .0 | .0 | 338 | 256 | 245 |
| 7 | ...do..... | Russell, spring at edge of Saline River, 4 miles due north of Russell [d] | ........ | .0 | .0 | 277 | 173 | 34 |

[a] Water was encountered at 15 feet and is probably of very local origin.
[b] Water discovered at 221 feet and is derived from Dakota sandstone.
[c] Put down in 1905. Is 80 rods northwest of Lindsay well and, like it, comes from the Dakota sandstone. Water rose 40 feet in well.
[d] Proposed public supply for Russell.

## SALINE COUNTY.

Saline County is underlain by Permian rocks, which are in places overlain by the eastern edge of the Dakota sandstone, which has been so eroded that peninsular-like extensions project out into the county or detached isolated masses cover considerable areas. The Permian rarely furnishes soft water, and so the chief hope of finding any must lie in locating wells in the Dakota sandstone below the gypsiferous and saliferous shales at the top of that formation.

But few tests of the waters of Saline County have been made and these are all analyses of well waters in fluviatile material at Salina (Table 82). All of these are very hard calcic alkaline waters.

TABLE 82.—*Analyses of underground waters from Saline County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1902. Sept. 23 | Salina, public supply of Salina Water Co. | 95 | Atchison, Topeka & Santa Fe Ry. | 36 | Trace. | 166 | 36 | 48 | 258 | ........ | 160 | ........ | 48 | ........ |
| 2 | 1906. Nov. 22 | Salina, reserve public supply of Salina Water Co.[a] | ........ | F. W. Bushong[b] | 27 | [c]2.0 | 161 | 31 | 66 | 0 | 534 | 180 | 3.5 | 39 | 764 |
| 3 | ...do..... | Salina, public supply, 12 wells of Salina Water Co. | 100 | .....do.[b] | 27 | [c]2.4 | 162 | 30 | 64 | 0 | 534 | 178 | .9 | 39 | 746 |
| 4 | 1908. Sept. | Salina, public supply, Salina Water Co. | ........ | Chicago, Rock Island & Pacific Ry. | ........ | [d]9 | 148 | 38 | 46 | 208 | ........ | 179 | ........ | 64 | 692 |
| 5 | 1902. Dec. 9 | Salina, artesian well of Chicago, Rock Island & Pacific Ry. | ........ | Kennicott Water Softener Co. | 39 | 33 | 124 | 37 | 81 | 198 | ........ | 221 | ........ | 56 | ........ |
| 6 | 1908. Feb. 13 | Salina, Kansas Ice & Cold Storage Co.'s 3 wells. | 78 | .....do | 19 | 2.9 | 166 | 22 | 76 | 243 | ........ | 178 | ........ | 70 | ........ |
| 7 | Mar. 31 | Salina, well one-half mile east of the station. | ........ | Union Pacific R. R. | 34 | 16 | 135 | 24 | 21 | 222 | ........ | 74 | ........ | 24 | 557 |

[a] Single big well fed by 4 flowing wells, Nos. 13, 14, 15, and 16, each 39 feet deep.
[b] Made at the laboratories of the University of Kansas.
[c] Al=.8.
[d] $SiO_2+Fe_2O_3+Al_2O_3$.

## SCOTT COUNTY.

Scott County lies on the High Plains, between Smoky Hill and Arkansas rivers. Its surface is covered with Tertiary deposits, which are underlain at a depth of 50 to 200 feet by Niobrara chalk. Under this chalk, whose thickness in this region probably ranges from 150 to 300 feet, increasing gradually to the northwest, there are about 400 feet of Benton shales underlain by Dakota sandstone. The beds all dip gently to the northeast. The depth to the sandstone is about 700 feet in the southeast corner of the county, gradually increasing to the northwest. So far as is known no attempts have been made to reach this sandstone. It doubtless contains water supplies, but would not afford surface flows, as the land is too high.[1]

The only analyses of waters in Scott County (Table 83) represent two wells in the Tertiary deposits at Scott. The waters are very much alike and are satisfactory.

Analyses 1 and 2 show soft calcic alkaline waters. Assay 2 is a test of water from a well in the Tertiary deposits and shows it to have low temporary and permanent hardness. Assay 3 indicates that the water which is taken from a well in a small basin west of Scott is like that of the wells sunk in the Tertiary. Assays 4 and 5 are tests of the waters of two wells in the Modoc Basin and show that as these waters contain large quantities of sulphates, they differ radically from the water obtained from wells in the Tertiary.

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 316.

TABLE 83.—*Analyses and assays of underground waters from Scott County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | 1902. Oct. 30 | Scott, surface well | ...... | Atchison, Topeka & Santa Fe Ry. | 49 | ... | 45 | 21 | 24 | 114 | 34 | 12 | .... | .... |
| 2 | .......... | Scott, 2 wells | 105 | Missouri Pacific Ry. | 53 | 0.8 | 50 | 19 | 19 | 122 | 31 | 7.5 | 8.6 | 311 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1907. Dec. 13 | Scott, well of Missouri Pacific Ry | ........ | 0.0 | 0.0 | 221 | Trace. | 15 |
| 2 | Dec. 12 | Scott, well of E. E. Coffin, lot 8, block 5, Case Addition | 75 | .0 | .0 | 227 | Trace. | 15 |
| 3 | Dec. 13 | Scott, well of A. B. Daugherty, SE. ¼ sec. 14, T. 18 S., R. 33 W., in a small basin west of the city | 15 | .0 | .0 | 207 | Trace. | 10 |
| 4 | Dec. 12 | Scott, well of E. E. Coffin in Modoc Basin, SW. ¼ sec. 31, T. 18 S., R. 32 W. | 45 | .0 | .0 | 290 | 313 | 24 |
| 5 | ...do..... | Scott, dug well of Si Lynch, in Modoc Basin, NW. ¼ sec. 36, T. 18 S., R. 33 W.[a] | 10 | .0 | .0 | 300 | 313 | 34 |

[a] Well is not walled up.

## SEDGWICK COUNTY.

Sedgwick County is entirely underlain by Permian rocks and as a rule hard waters are to be expected.

Analyses 1, 2, 3, 5, and 6 (Table 84) are tests of wells in Ninnescah Valley. Of these analyses, 1, 2, and 3 show soft calcic alkaline waters, while 5 and 6 denote hard calcic alkaline waters. Analysis 4 indicates a hard calcic alkaline water, high in chlorides.

The waters from Wichita (analyses 7 to 13) differ distinctly from the preceding; they come from the underflow of Arkansas River, whereas the others do not. All these waters are hard and salty. The assay indicates that the city water is highly mineralized with sulphates, chlorides, and bicarbonates.

TABLE 84.—*Analyses and assay of underground waters from Sedgwick County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1902. Oct. 14 | Cheney, surface well | | Atchison, Topeka & Santa Fe Ry. | 23 | 1.8 | 47 | 17 | 12 | 110 | | 11 | 12 | | |
| 2 | 1901. May 24 | Clearwater, well | | do | | | 68 | 17 | 33 | 127 | | 27 | 49 | 39 | 360 |
| 3 | 1902. Oct. 14 | Clearwater, surface well | | do | 24 | 2.2 | 71 | 21 | 24 | 164 | | 26 | 12 | | |
| 4 | Oct. 21 | Goddard, surface well | | do | 60 | 3.2 | 145 | 14 | 52 | 191 | | 36 | 133 | | |
| 5 | Dec. 11 | Peck, surface well of Chicago, Rock Island & Pacific Ry. | | do | 23 | 2.7 | 90 | 8.3 | 40 | 156 | | 45 | 29 | | |
| 6 | 1908. Sept. | Peck, well | 59 | Chicago, Rock Island & Pacific Ry. | | 3.4 | 69 | 16 | 42 | 138 | | 52 | 30 | | 350 |
| 7 | 1897. June 14 | Wichita, city well | | do | 14 | 3.6 | 90 | 23 | 348 | 86 | | 235 | 515 | 62 | |
| 8 | 1902. Dec. 9 | Wichita, city water supply, well of Chicago, Rock Island & Pacific Ry. | | Kennicott Water Softener Co. | 22 | 3.5 | 101 | 23 | 271 | 152 | | 138 | 382 | | |
| 9 | 1897. Aug. 2 | Wichita, Atchison, Topeka & Santa Fe Ry. well. | | Atchison, Topeka & Santa Fe Ry. | 19 | | 233 | 37 | 162 | 213 | | 388 | 233 | 62 | 1,346 |
| 10 | 1902. Sept. 23 | Wichita, well | | do | 13 | | 106 | 20 | 165 | 218 | | 210 | 206 | | |
| 11 | 1904. Apr. 1 | Wichita, surface well of Jno. Cudahy & Co. | | Kennicott Water Softener Co. | 18 | 3.5 | 108 | 28 | 68 | 247 | | 112 | 121 | | |
| 12 | 1905. Dec. 24 | Wichita, Wichita Ice & Cold Storage Co.'s well. | 33 | do | 16 | 2.9 | 266 | 59 | 144 | 180 | | 512 | 221 | | |
| 13 | 1908. Sept. | Wichita, well 500 feet from tank of Chicago, Rock Island & Pacific Ry. | 32 | Chicago, Rock Island & Pacific Ry. | | [a] 5 | 293 | 51 | 174 | 170 | | 613 | 279 | | 1,585 |
| | | ASSAY. | | | | | | | | | | | | | |
| 1 | 1907. Jan. 21 | Wichita, city water, 22 wells | 42 | | | .0 | | | | .0 | 338 | 530 | 331 | | |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.

### SEWARD COUNTY.

Seward County comprises a portion of Cimarron Valley in southwest Kansas. The greater portion of its surface is covered by Tertiary deposits, which are underlain by Dakota sandstone to the north and by "Red Beds" to the south. Water is usually obtained from the coarse materials at the base of the Tertiary grit, and to the north by some of the wells from the Dakota sandstones. A State well 176 feet deep, sunk just northwest of Liberal, obtains a moderate amount of water from the Tertiary grit beds. A well 485 feet deep, in Liberal, bored by the Rock Island Railroad Co., is reported to have found sandy clay with layers of sand rock all the way down, so that apparently it did not reach the "Red Beds." The well yields a moderate supply of water, which rises within 125 feet of the surface. A similar well at Arkalon is 300 feet deep.

No reports have been received of any attempts to penetrate the "Red Beds" for water supplies, but wells in other parts of the region show that the waters from the "Red Beds" are usually too much mineralized to be of use.[1]

Both analyses in Table 85 indicate calcic magnesic alkaline waters of high permanent hardness, that of the well at Arkalon being the more marked.

The assays are tests of the waters of several wells in Liberal which locally are believed to differ considerably from each other. As a matter of fact the waters are much alike; all have low temporary and moderate permanent hardness. Assay 3 is a test of a water from the Dakota sandstone.

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 316.

TABLE 85.—*Analyses and assays of underground waters from Seward County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| | 1908. | | | | | | | | | | | | | |
| 1 | Sept. | Arkalon, well | 90 | Chicago, Rock Island & Pacific Ry. | ... | [a]5 | 80 | 23 | 33 | 118 | .... | 139 | 18 | 415 |
| 2 | ...do | Liberal, well | 165 | ...do | ... | [a]3.9 | 56 | 28 | 4.2 | 118 | .... | 50 | 12 | 273 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1907. | | | | | | | |
| 1 | Nov. 5 | Liberal, well of city waterworks | 175 | 0.0 | 0.0 | 213 | 47 | 15 |
| 2 | ...do | Liberal, well of Alexander McCord | 156 | .0 | .0 | 213 | Trace. | 15 |
| 3 | ...do | Liberal, well of Chas. Calvert [b] | 165 | Tr. | .0 | 213 | Trace. | 15 |
| 4 | ...do | Liberal, well of McDermott's laundry | 227 | .0 | .0 | 227 | Trace. | 15 |
| 5 | ...do | Liberal, well of Jas. Dalton | 160 | .0 | .0 | 222 | 38 | 10 |
| 6 | ...do | Liberal, well No. 1 of Chicago, Rock Island & Pacific Ry. | 241 | .0 | .0 | 221 | 44 | 15 |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.

[b] Well is in the Dakota sandstone.

## SHAWNEE COUNTY.

Shawnee County is wholly underlain by Pennsylvanian rocks, consequently the outlook for soft waters is unfavorable, though it may be that in the glacial deposits there are satisfactory waters. In the valley of the Kansas considerable fluviatile material (see Brown County) has accumulated and is an important source of water supply.

All of the tests (Table 86) are of waters from the immediate valley of Kansas River and indicate hard waters, some of which carry in solution an appreciable amount of iron and others noticeable amounts of chlorides.

TABLE 86.—*Analyses of underground waters from Shawnee County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine ($Cl_4$). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1908. Mar. 3 | Rossville well | 33 | Union Pacific R. R. | 40 | 10 | 118 | 18 | 39 | 188 | 67 | 50 | ........ | 535 |
| 2 | 1899. Oct. 30 | Topeka, well at shop pump house | ........ | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 112 | 20 | 61 | 152 | 107 | 91 | 115 | 658 |
| 3 | 1898. Feb. 21 | Topeka, south driven well at shops | ........ | do | 41 | ........ | 102 | 22 | 111 | 167 | 110 | 137 | 113 | 808 |
| 4 | 1903. Mar. 25 | Topeka, drinking well at new shops | ........ | do | ........ | ........ | 70 | 18 | 50 | 92 | 115 | 57 | 44 | 460 |
| 5 | 1902. Nov. 1 | Topeka, well of Mr. Page | ........ | do | ........ | ........ | 217 | 35 | 76 | 190 | 292 | 163 | 106 | 1,085 |
| 6 | Nov. 15 | Topeka, well | ........ | do | 22 | 1 | 54 | 12 | 32 | 93 | 48 | 23 | ........ | ........ |
| 7 | 1901. Apr. 10 | Topeka, surface well, bottom of well point. | ........ | do | ........ | ........ | 90 | 16 | 70 | 129 | 203 | 85 | 36 | 527 |
| 8 | 1902. Dec. 10 | Topeka, Chicago, Rock Island & Pacific Ry. well. | ........ | Kennicott Water Softener Co. | 19 | 10 | 86 | 17 | 85 | 158 | 20 | 129 | ........ | ........ |
| 9 | 1908. Sept. | Topeka, Chicago, Rock Island & Pacific Ry. well, 80 feet from tank. | 41 | Chicago, Rock Island & Pacific Ry. | ........ | a 7.7 | 132 | 32 | 62 | 194 | 151 | 82 | ........ | 661 |
| 10 | Mar. 3 | Topeka, 2 wells | 56 | Union Pacific R. R. | 22 | 3.8 | 79 | 14 | 44 | 126 | 58 | 49 | ........ | 398 |
| 11 | 1898. Feb. 7 | Topeka, city water, wells | ........ | Atchison, Topeka & Santa Fe Ry. | 19 | ........ | 94 | 19 | 84 | 131 | 106 | 116 | 80 | 652 |
| 12 | 1904. Nov. 5 | Topeka, Topeka Laundry Co. well | 65 | Kennicott Water Softener Co. | 19 | 1.8 | 118 | 22 | 48 | 178 | 94 | 67 | ........ | ........ |
| 13 | 1908. Sept. | Willard, 50 feet from tank | 41 | Chicago, Rock Island & Pacific Ry. | ........ | a 3.8 | 151 | 24 | 19 | 235 | 88 | 23 | ........ | 543 |

a $SiO_2+Fe_2O_2+Al_2O_3$.

## SHERIDAN COUNTY.

Sheridan County is a typical High Plains area, thickly covered by "mortar beds" or Tertiary grit. The underlying formation is in part Niobrara chalk, which is exposed in the valley of Salina River in the southeast corner of the county, and in part Pierre shale, which probably occupies the higher portion of the region to the northwest. The depth to Dakota sandstone is probably about 800 feet in the southeast part of the county and 1,250 feet in the northwest part, the beds dipping gently to the north.[1]

The only analysis presented in Table 87 indicates a calcic magnesic alkaline water from the Tertiary deposits. The assays are all tests of waters in Hoxie. Assay 1 shows the water that came from a well in the valley of Sand Creek, which was dry at the time the sample was taken, to be rather hard. The two other waters examined were taken from wells high above the creek bottom. They proved to be soft and quite like the waters of many wells that are fed from the Tertiary.

TABLE 87.—*Analysis and assays of underground waters from Sheridan County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1908. Sept. | Selden, well | 28 | Chicago, Rock Island & Pacific Ry. | [a]8.2 | 44 | 22 | 26 | 120 | .... | 30 | 10 | 259 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. Sept. 28 | Hoxie, well of E. T. Crum Elevator & Milling Co. | 22 | | .0 | ... | ... | .... | .0 | 290 | 40 | 20 | .... |
| 2 | ...do..... | Hoxie, well of R. M. Martin.[b] | 85 | | .0 | ... | ... | .... | .0 | 241 | Tr. | 15 | .... |
| 3 | ...do..... | Hoxie, well of Wm. Dietz. | 103 | | .0 | ... | ... | .... | .0 | 233 | Tr. | 15 | .... |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.

[b] Put down in 1886.

## SHERMAN COUNTY.

Sherman County lies on the High Plains, chiefly on the divide between Republican and Arkansas valleys, its surface thickly covered by Tertiary deposits lying on Pierre shale. One of the State test wells, located 3 miles northeast of Goodland, reached a depth of 166 feet, all in Tertiary deposits, and obtained a large supply of water for pumping, probably from the basal beds. The Pierre shale in this vicinity is doubtless nearly 1,000 feet thick, and the underlying Niobrara and Benton formations are probably 950 feet thick, as in

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, p. 317.

the region to the east and south. These beds dip gently to the north. The Dakota sandstone should lie about 1,500 feet below the surface in the southeast part of the county and at a depth of at least 2,500 feet in the northwest part. All of the land is too high for flowing water from the Dakota sandstone to be obtainable, although undoubtedly the water-bearing beds of this formation extend under the county and would yield water supplies for deep pump wells.[a]

The depth to the water varies slightly on account of the varying conditions of altitude of the surface, but in most places water is reached at from 150 to 200 feet and frequently will rise quite perceptibly in the well. It is not unusual for the drill to find a bed of water-bearing sand above a stratum of clay, below which is another bed of water-bearing sands, the water in which will rise to the level of the first water reached. Some wells even have passed a third water-bearing stratum before the Cretaceous floor was reached. A neck of the Cretaceous shales exposed along one of the tributaries of the Smoky Hill passes up into the southeastern part of Sherman County, producing an area in that part of the county over which water is hard to obtain.[b]

The two analyses presented in Table 88 record tests of soft calcic alkaline waters from wells in the Tertiary deposits. The assays are all of waters in Goodland. A comparison of assays 1 and 2 makes it apparent that the water from the well of the light and power company, which is used to eke out the city supply, is somewhat harder than the water from the city wells. Assay No. 3 indicates a well like that of the light and power company. The other assays show very satisfactory waters.

TABLE 88.—*Analyses and assays of underground waters from Sherman County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | 1908. Sept. | Kanorado, well | 145 | Chicago, Rock Island & Pacific Ry. | c28 | 37 | 17 | 8 | 87 | .... | 24 | 6 | 207 |
| 2 | ...do | Goodland, well | 180 | ...do | c18 | 38 | 16 | 13 | 89 | .... | 29 | 7.8 | 211 |

[a] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 317.
[b] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 100.
[c] $SiO_2+Fe_2O_3+Al_2O_3$.

TABLE 88.—*Analyses and assays of underground waters from Sherman County*—Contd.

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1907. | | | | | | | |
| 1 | Sept. 26 | Goodland, city waterworks, 2 wells | 178 | 0.0 | 0.0 | 207 | Trace. | 15 |
| 2 | ...do... | Goodland, well of Goodland Light & Power Co.[a] | 160 | .0 | .0 | 194 | 49 | 41 |
| 3 | Sept. 27 | Goodland, well at southwest corner of Courthouse Square | 160 | .0 | .0 | 197 | 59 | 20 |
| 4 | ...do... | Goodland, well of Chicago, Rock Island & Pacific Ry | 165 | .0 | .0 | 184 | Trace. | 15 |
| 5 | ...do... | ...do... | 187 | 1.0 | .0 | 188 | ...do... | 10 |

[a] Used to eke out city supply.

## SMITH COUNTY.

Smith County extends north from North Fork of Solomon River, in the north-central portion of the State. The north half of the county is covered by Tertiary deposits, under which the Niobrara formations appear to the south, Benton shales being exposed in the southeast corner of the county. The formations dip gently northward. The Dakota sandstone is from 300 to 500 feet beneath the surface in the southeastern part of the county, and the depth gradually increases northward to 800 feet in the highest lands of the northwest corner of the county.

The principal water supplies are obtained from wells of moderate depth in the Tertiary and in alluvial deposits. Some deeper wells obtain small amounts of water in the Niobrara and Benton formations, but usually in these the waters are insufficient in quantity or poor in quality. Several deep borings have been sunk. One at Smith Center, 600 feet deep, was all in shale, not being quite deep enough to reach the Dakota sandstone. Considerable water was found at a depth of 590 feet, which rose to within 390 feet of the surface, but was too salty to be of use. Apparently, it was derived from the salty sandstones and shales which usually occur under the Benton shales. Twelve miles southeast of Smith Center, sec. 5, T. 5 S., R. 12 W., a well 540 feet deep passed through a thick body of dark shales into 5 feet of sandstone containing a large volume of water, which rose to within 140 feet of the surface, but this water is reported as too salty for use. Near Cedarville a well 400 feet or more in depth failed to reach the bottom of the shale. Unfortunately no well has been sunk sufficiently deep to test thoroughly the Dakota sandstone waters in this county, for although water from the Dakota would not flow at the surface, it would doubtless prove to be of better quality in the lower portion of the formation, and, having a large volume and considerable head, would prove an important source of supply for deep pump wells.[1]

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 317-318.

All of the analyses presented in Table 89 show calcic alkaline waters. Analyses 1 and 2 indicate waters of considerable permanent and high temporary hardness. Analysis 3 denotes a much harder water than either of the two preceding, and analysis 4 is a test of a water that has little temporary and decided permanent hardness. The assay indicates a water of great permanent and temporary hardness.

TABLE 89.—*Analyses and assay of underground waters from Smith County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | .......... | Harlan, well........ | 51 | Missouri Pacific Ry. | 28 | 1.5 | 104 | 13 | 43 | 179 | 73 | 23 | 7.5 | 474 |
| 2 | 1908. Sept. | Kensington, well, 60 feet from tank. | 60 | Chicago, Rock Island & Pacific Ry. | ... | a17 | 118 | 12 | 26 | 174 | 63 | 31 | .... | 440 |
| 3 | ...do.... | Lebanon, well, 6,000 feet from tank. | 24 | ......do.............. | ... | a60 | 176 | 14 | 47 | 278 | 107 | 17 | .... | 716 |
| 4 | ...do.... | Smith Center, well.. | 200 | ......do.............. | ... | a2. | 58 | 15 | 15 | 80 | 71 | 22 | .... | 274 |
| | | ASSAY. | | | | | | | | | | | | |
| 1 | Sept. 5 | Gaylord, public well | 40 | .................... | ... | .0 | ... | ... | .... | 0.354 | (b) | 94 | .... | .... |

a $SiO_2+Fe_2O_3+Al_2O_3$. b $SO_4$ greater than 626.

## STAFFORD COUNTY.

Stafford County lies on the south side of the Great Bend of Arkansas Valley and is mostly a region of high plains. Its entire area is covered by Tertiary and later deposits, which are underlain throughout by the Dakota sandstone.

Most of the wells in the county are 20 to 70 feet deep and obtain their water supplies from the Tertiary or later deposits. Doubtless wells sunk into the Dakota sandstone would yield additional supplies if they were required. The Dakota sandstone is underlain at a moderate depth by the "Red Beds," which contain saline waters and are probably very thick.[1]

In the northeastern part of the county are two salt marshes that are believed to be fed by springs which may have their source in the saliferous shales of the Dakota sandstone.

The analyses, Table 90, show soft calcic alkaline waters; the assays also indicate soft waters.

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 319.

TABLE 90.—*Analyses and assays of underground waters from Stafford County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| | 1902. | | | | | | | | | | | | | | |
| 1 | Oct. 1 | St. John, surface well. | ... | Atchison, Topeka & Santa Fe Ry. | 18 | 0.5 | 57 | 6.9 | 30 | 102 | .... | 23 | 29 | .... | .... |
| 2 | .......... | Seward, well......... | 68 | Missouri Pacific Ry. | 15 | .8 | 70 | 4.7 | 15 | 113 | .... | 18 | 15 | 7.2 | 260 |
| 3 | .......... | Stafford, well....... | 80 | .....do............ | 23 | 2.7 | 83 | 10 | 32 | 140 | .... | 17 | 49 | 31 | 390 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1907. | | | | | | | |
| 1 | Dec. 3 | St. John, well of Atchison, Topeka & Santa Fe Ry. | ...... | 0.0 | 0.0 | 222 | Trace. | 26 |
| 2 | Dec. 4 | Stafford, city waterworks well.................. | 50 | .0 | .0 | 174 | Trace. | 44 |
| 3 | ...do.... | Stafford, well of Pacific Elevator Co............. | 50 | .0 | .0 | 232 | Trace. | 50 |
| 4 | ...do.... | Stafford, well of Wm. Sloan...................... | ...... | .0 | .0 | 215 | Trace. | 72 |
| 5 | ...do.... | Stafford, well of Earl Akers...................... | 90 | .0 | .0 | 227 | Trace. | 104 |

## STANTON COUNTY.

The surface of Stanton County is almost entirely covered by the Tertiary deposits of the High Plains. The Dakota sandstone is exposed along some of the deeper valleys in the western portion of the county and is known to underlie the Tertiary deposits in the region to the east and south. It has been reached by a 420-foot well at Johnson and by other wells in the vicinity. The water of these wells is of satisfactory quality and good volume, but its head is sufficient to bring it only to within 150 to 180 feet from the surface. The "Red Beds" which underlie the sandstone have not been penetrated in this county; they doubtless contain water and might possibly afford a flow, as at Richfield, Morton County.[1]

Judge William Easton Hutchinson reports that wells are rather shallow along Bear Creek and in the southern part of the county along a draw which drains east and west, emptying in an indefinite manner into North Fork of Cimarron River. Furthermore, the depth to water in the extreme southern part of the county and a part of the western portion is somewhat more than 100 feet on an average, but

[1]Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 319.

from a point near the center of the county to the eastern edge the depth gradually diminishes and an abundance of good water is reached at a depth ranging from 40 to 50 feet.

So far as is known, no tests have been made to show the quality of waters in Stanton County.

## STEVENS COUNTY.

Stevens County lies in the big bend of Cimarron River near the southwest corner of the State. Its surface is heavily covered by Tertiary deposits which to the north lie on Dakota sandstone and to the south on the "Red Beds." The location of the line of division between the two underlying formations is not definitely ascertained. Most of the water supplies in this county are obtained from wells of moderate depth in Tertiary sands and gravels; possibly some wells reach the Dakota sandstone, but its precise depth and relations are not known. Apparently it lies from 200 to 300 feet below the surface, the depth probably being less in the Cimarron Valley. No deep wells have yet been sunk in the underlying "Red Beds," but possibly the same horizon that yields the saline waters in the wells at Richfield, in Morton County, might be found.[1]

Judge William Easton Hutchinson says that in the valley of the Cimarron wells are shallow, and that over the rest of the county wells are 75 to 100 feet deep and have an abundance of water.

In the southern tier of counties, including Morton, Stevens, Seward, Meade, and Clark counties, in addition to the ordinary ground water, two other features are of special interest. The Cimarron River valleys aggregate about 250 square miles of unusually smooth even land, with the water in great quantities lying at a depth of from 10 to 30 feet.[2]

It is not known that any tests have been made to determine the quality of the waters of Stevens County.

## SUMNER COUNTY.

Sumner County is entirely underlain by Permian rocks, and the prospect for soft waters is poor.

Analyses 3, 8, and 11, Table 91, show calcic magnesic alkaline waters. Analyses 4 and 7 indicate calcic alkaline waters. Analyses 1 and 2 denote sodic calcic saline waters. Analysis 12 shows a calcic saline water. Analyses 3, 8, and 11, tests of calcic magnesic alkaline waters that are very unsuitable for domestic and industrial use. Analyses 6 and 10 show calcic sodic saline waters. Analyses 9 and 13 denote calcic magnesic saline waters.

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[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 318.

[2] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 103.

Assays 1 to 9, Table 91, are tests of several well waters in Argonia. Of these waters only two (those of which assays 1 and 4 are tests) are soft; the rest are very hard, and all are high in chlorides. Assays 10 and 11 are tests of the two wells that form the public water supply of Conway Springs. Assay 10 denotes a very soft water and assay 11 one that has great permanent hardness and high chlorides. Assays 10 and 11 are tests of wells at Mulvane; the former indicates a hard water and the latter one that is soft. Assay 14 shows a very hard water.

TABLE 91.—*Analyses and assays of underground waters from Sumner County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | 1897. July 22 | Belle Plaine, driven well. | ... | Atchison, Topeka & Santa Fe Ry. | ... | .... | 115 | 26 | 342 | 259 | 61 | 454 | 46 | 1,311 |
| 2 | 1898. Sept. 23 | Belle Plaine, test well. | ... | .....do........... | ... | 25 | 126 | 29 | 328 | 205 | 87 | 466 | 108 | 1,385 |
| 3 | .......... | Belle Plaine, 4 sand pits. | ... | Missouri Pacific Ry. | 25 | 16 | 41 | 16 | 16 | 84 | 27 | 26 | 72 | 329 |
| 4 | 1900. July 30 | Caldwell, new well.... | ... | Atchison, Topeka & Santa Fe Ry. | ... | .... | 24 | 2.2 | 8.1 | 82 | 12 | 27 | 17 | 118 |
| 5 | 1902. Sept. 9 | Johnstons, well at red barn. | ... | .....do........... | ... | .... | 79 | 20 | 126 | 317 | .... | 17 | 68 | 632 |
| 6 | .......... | Johnstons, hotel well.. | ... | .....do........... | ... | .... | 47 | 8.9 | 49 | 53 | 136 | 24 | 36 | 360 |
| 7 | Sept. 23 | Mulvane, well......... | ... | .....do........... | 24 | .... | 87 | 18 | 24 | 124 | 113 | 12 | ... | ..... |
| 8 | Oct. 21 | South Haven, surface well. | ... | .....do........... | 15 | 3.5 | 92 | 31 | 45 | 190 | 68 | 48 | ... | ..... |
| 9 | Mar. 11 | Wellington, well...... | ... | .....do........... | ... | .... | 247 | 105 | 14 | 226 | 502 | 126 | 207 | 1,433 |
| 10 | June 10 | Wellington, private well. | ... | .....do........... | ... | .... | 294 | 46 | 224 | 63 | 783 | 152 | 243 | 1,811 |
| 11 | Jan. 20 | Wellington, well at Hunter's mill. | ... | .....do........... | ... | .... | 143 | 50 | 40 | 221 | 150 | 90 | 50 | 750 |
| 12 | ...do.... | Wellington, test wells of Atchison, Topeka & Santa Fe Ry. | ... | .....do........... | ... | .... | 279 | 41 | 50 | 182 | 469 | 129 | 77 | 1,232 |
| 13 | 1908. Sept. | Wellington, well 95 feet from tank of Chicago, Rock Island & Pacific Ry. | 33 | Chicago, Rock Island & Pacific Ry. | ... | *a*7 | 186 | 75 | 54 | 208 | 410 | 83 | ... | 1,045 |

*a* $SiO_2+Fe_2O_3+Al_2O_3$.

TABLE 91.—*Analyses and assays of underground waters from Sumner County*—Contd.

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1908. Jan. 10 | Argonia, well opposite the bank and Smith's livery. | 30 | 0.0 | 0.0 | 277 | Trace. | 67 |
| 2 | ...do.... | Argonia, well of Arlington Hotel..... | ........ | .0 | .0 | 272 | 344 | 268 |
| 3 | ...do.... | Argonia, well of H. C. Hetrick on Main Street. | ........ | .0 | .0 | 214 | 94 | 130 |
| 4 | ...do.... | Argonia, well at Smith's livery....... | 25 | Trace. | .0 | 249 | Trace. | 161 |
| 5 | ...do.... | Argonia, well of Badger Lumber Co.. | 32 | .0 | .0 | 222 | 82 | 422 |
| 6 | 1907. May 16 | Belle Plaine, public well[a]............ | 26 | .0 | .0 | 176 | 86 | 622 |
| 7 | ...do.... | Belle Plaine, well at depot of Atchison, Topeka & Santa Fe Ry. | 30 | .0 | .0 | 140 | 104 | 75 |
| 8 | 1908. Jan. 7 | Caldwell, well on Main Street, opposite Detrick's store.[b] | 40 | .0 | .0 | 204 | 115 | 136 |
| 9 | ...do.... | Caldwell, well on Fifth Street at Drake & Towner's smithy. | 40 | .0 | .0 | 184 | 124 | 114 |
| 10 | Jan. 10 | Conway Springs, city supply, east well. | 65 | .0 | .0 | 163 | 573 | 83 |
| 11 | ...do.... | Conway Springs, city supply, west well. | 18 | .0 | .0 | 65 | Trace. | 26 |
| 12 | 1907. May 16 | Mulvane, well on Main Street opposite Minnich's store.[c] | 32 | .0 | .0 | 232 | 115 | 55 |
| 13 | ...do.... | Mulvane, well on Mulvane Street, block 35, lot 3 and E. ½ lot 4. | 40–45 | .0 | .0 | 212 | Trace. | 50 |
| 14 | 1898. Jan. 8 | Wellington, 2 wells of Wellington Ice & Cold Storage Co.[d] | 45 | .0 | .0 | 400 | 492 | 188 |

[a] Put down in 1900. [b] Put down about 1878. [c] Put down about 1891. [d] Used for condensers.

## THOMAS COUNTY.

In Thomas County the conditions are similar to those in Sherman County, but owing to the slightly diminished altitude of the High Plains and the slight rise to the south of the underlying formations the Dakota sandstone is probably nearer the surface, its depth being about 1,600 feet in the center of the county, 1,250 feet in the southeast corner, and 2,000 feet in the northwest corner. A well at Colby reached a depth of 200 feet and obtained from the Tertiary "mortar beds" a satisfactory supply for pumping.[1]

Both the analyses and assays presented in Table 92 are tests of soft waters from the Tertiary deposits.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 319.

TABLE 92.—*Analyses and assays of underground water from Thomas County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | |
| 1 | 1908. Sept. | Brewster, well | 155 | Chicago, Rock Island & Pacific Ry. | a8.2 | 38 | 19 | 29 | 105 | ... | 41 | 15 | 256 |
| 2 | ...do..... | Colby, well | 147 | .....do | a24 | 52 | 19 | 16 | 124 | ... | 21 | 9.7 | 266 |
| | | ASSAYS. | | | | | | | | | | | |
| 1 | 1907. Sept. 25 | Colby, well of G. I. Idzorek. | 108 | | .0 | ... | ... | .... | .0 | 245 | Tr. | 10 | .... |
| 2 | ...do..... | Colby, well of Chicago, Rock Island & Pacific Ry. | 145 | | .0 | ... | ... | .... | .0 | 245 | Tr. | 10 | .... |

a $SiO_2+Fe_2O_3+Al_2O_3$.

## TREGO COUNTY.

Trego County, in west-central Kansas, comprises a portion of Smoky Hill Valley. The higher lands are thickly covered with Tertiary deposits; the valleys expose the Niobrara formation, which underlies the entire county, attaining a thickness of 200 to 300 feet in the west part, but thinning gradually to the east, owing to the erosion of its upper surface. The Niobrara is underlain by about 400 feet of Benton formation, which in turn rests on the Dakota sandstone, the beds all dipping gently to the north. The sandstone lies about 400 feet below the surface in Smoky Hill Valley, 500 feet below in the lower lands along the east margin of the county, and about 900 feet below in the northwest townships.

None of the wells reported have reached the sandstone, although several have penetrated the overlying formations for several hundred feet. One of these wells, 3 miles north of Smoky Hill River, near the west border of the county, is said to have the following record:

*Record of well north of Smoky Hill River, near western border of Trego County, Kans.*

| | Feet. |
|---|---|
| Clay | 0– 40 |
| Blue shale | 40–150 |
| White chalk, with small water supply | 150–190 |
| Blue shale | 190–446 |

A well 3 miles south of the river has a similar record. In a well 12 miles southwest of Wakeeney (sec. 12, T. 14 S., R. 24 W.) a well 438 feet deep ending in black shale of the Benton formation obtains 50 gallons a day of satisfactory water at a depth of 150 feet below the chalk. Many wells in the higher lands in the central part of the county obtain satisfactory water supplies in the gravels and sands of the Tertiary deposits, but usually fail to find any water in the underlying shale. The alluvial formations along the bottoms of Smoky Hill and Saline rivers and some other streams contain considerable water.[1]

All the waters of which tests are recorded in Table 93 are from the Tertiary deposits and all are soft except that characterized by analysis 2 as having high permanent hardness. No tests were made of the waters of any of the deep wells nor of those of the shallow wells in the southern part of the county.

TABLE 93.—*Analyses and assays of underground waters from Trego County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1908. Mar. 16 | Collyer, well 389 feet east of Union Pacific R. R. station. | 99 | Union Pacific R. R. | 40 | Tr. | 64 | 16 | 11 | 116 | .... | 32 | .... | 17 | 294 |
| 2 | Apr. 20 | Wakeeney, well 1,800 feet east of Union Pacific R. R. station. | 72 | .....do.......... | 48 | 1.2 | 84 | 18 | 36 | 113 | .... | 94 | 1.6 | 55 | 452 |
| 3 | Apr. 21 | Wakeeney, well one-half mile west from Union Pacific R. R. tank. | 78 | .....do.......... | 39 | 1.9 | 43 | 8 | 20 | 90 | .... | 15 | .... | 13 | 230 |
| | 1907. | ASSAYS. | | | | | | | | | | | | | |
| 1 | Sept. 21 | Wakeeney, city well east of Court-house Square. | *a*100 | .................. | ... | 0.0 | ... | ... | .... | 0.0 | 229 | Tr. | .... | 26 | .... |
| 2 | ...do.... | Wakeeney, well of J. R. Wilson on Russell Street. | 90 | .................. | ... | .0 | ... | ... | .... | .0 | 211 | .do. | .... | 20 | .... |

*a* Depth of the average well in city.

## WABAUNSEE COUNTY.

The southwest part of Wabaunsee County is underlain by Permian beds and the rest by rocks of the Pennsylvanian series. Soft waters are therefore not obtainable, except possibly in the northern part of the county, where there are glacial deposits.

The two analyses presented in Table 94 show very hard calcic alkaline waters. The assays were all made at Alma. The first three show soft waters, all of which are from wells in the hilly part of the city high above the Mill Creek bottoms. The last two assays indicate very hard waters in the Mill Creek bottoms in the flat part of the city.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, pp. 319, 320, 835.

TABLE 94.—*Analyses and assays of underground waters from Wabaunsee County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium ($Na_2+K$). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | 1902. Dec. 10 | McFarland, Chicago, Rock Island & Pacific Ry. well. | ... | Kennicott Water Softener Co. | 22 | 10 | 125 | 23 | 35 | 209 | ... | 90 | 29 | ... |
| 2 | 1908. Sept. | Volland, well 150 feet from tank of Chicago, Rock Island & Pacific Ry. | ... | Chicago, Rock Island & Pacific Ry. | ... | [a]6.8 | 130 | 31 | 5.7 | 202 | ... | 101 | 16 | 493 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1907. Aug. 14 | Alma, well in courthouse yard on Kansas Avenue [b] | 50 | 1.5 | 0.0 | 267 | Trace. | 34 |
| 2 | ...do.... | Alma, well of C. M. Rose, Kansas Avenue [c] | 50 | .0 | .0 | 329 | 37 | 109 |
| 3 | ...do.... | Alma, well at new schoolhouse, Missouri Street [d] | 75–80 | .0 | .0 | 380 | Trace. | 29 |
| 4 | ...do.... | Alma, well at New Commercial Hotel | 35 | 1.0 | .0 | 344 | 168 | 109 |
| 5 | ...do.... | Alma, well at L. Schroeder's restaurant, Missouri Street [e] | 40 | .0 | .0 | 356 | 256 | 218 |

[a] $SiO_2+Fe_2O_3+Al_2O_3$.
[b] Sunk in 1879, very old pipe.
[c] Drilled about 1887.
[d] Drilled in 1906.
[e] Put down August 10, 1907.

## WALLACE COUNTY.

In Wallace County the High Plains are deeply trenched by the headwaters of branches of Smoky Hill River. Altitudes in the county range from 3,000 feet above sea level in the valley east of Wallace to slightly over 4,000 feet in the higher lands along the State line. The plains are occupied by Tertiary deposits, but in Smoky Hill Valley the underlying Pierre shales are exposed. These shales are probably not over 300 feet thick in the valley east of Wallace, but they thicken to the northwest. The combined thickness of the Benton and Niobrara formations in this county is probably about 1,000 feet, for the Niobrara beds thicken to the west. The Dakota sandstone, therefore, lies at a depth of about 1,100 feet in Smoky Hill Valley, at the eastern margin of the county, about 1,500 feet at Sharon Springs, and probably 2,000 feet in the northwest corner of the county. The results of the well at Horace, in the next county south, indicate that the Dakota sandstone contains a large volume of water, whose head, however, will take it only to an altitude of 2,938 feet; and although the head increases somewhat to the north, it is still insufficient to afford flows except probably for a few miles in Smoky Hill Valley south and east of Wallace.

The principal water supplies are obtained from the lower portion of the Tertiary deposits and from the alluvial sands and gravels in the large valleys. A number of attempts have been made to obtain water from the underlying shales. Near the town of Wallace wells have been sunk to 400 and to 448 feet, all in shale below the Tertiary deposits, without obtaining much water. A short distance northwest of Wallace a boring 800 feet deep failed to reach the Dakota sandstone.[1]

The only analysis in Table 95 is of a very soft water at Weskan. All of the assays, and particularly No. 1, show hard water.

TABLE 95.—*Analysis and assays of underground waters from Wallace County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | | |
| 1 | 1908. Mar. 16 | Weskan, well 100 feet west of Union Pacific R. R. depot. | 134 | Union Pacific R. R. | 27 | 5.7 | 41 | 10 | 17 | 92 | 9.1 | 12 | 216 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1907. Sept. 24 | Sharon Springs, well at Wildman's livery barn on north side of Eagle Tail Creek. | 30 | .0 | .0 | 143 | (a) | 242 |
| 2 | ...do.... | Sharon Springs, well of J. A. Johnson on south side of Eagle Tail Creek. | 24 | .0 | .0 | 356 | 100 | 15 |
| 3 | ...do.... | Sharon, new well of Union Pacific R. R. on south side of Eagle Tail Creek.[b] | 14 | .0 | .0 | 369 | 82 | 15 |

[a] $SO_4$ greater than 626.
[b] Under construction at time sample was taken; to be 40 feet deep when completed.

## WASHINGTON COUNTY.

Washington County lies between Republican and Little Blue Valleys in the north-central portion of the State. The Dakota sandstone is the prevailing formation over the greater part of the county, but in Little Blue Valley, in the southeast corner, the underlying Permian beds appear.

Many wells of moderate depth obtain water from the Dakota sandstone. A boring put down in the village of Washington to a depth

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 320.

of 2,200 feet obtained no noteworthy water supply, and thus indicates that the Permian shales, limestones, and sandstones, which underlie the Dakota sandstone in this region, do not contain water.[1][a]

Glacial deposits occur in parts of this county and may possibly yield supplies of good water.

Analysis 1 (Table 96) shows the city water of Greenleaf to be hard. Washington city water, according to analysis 3, has low temporary and high permanent hardness, but assay 5, which was made two years later and which is believed to correctly represent the water at the present time, shows the water to have a high temporary hardness and very great permanent hardness. Analysis 4 denotes a hard calcic magnesic saline water that would probably prove corrosive in steam boilers. Analysis 2 indicates a very hard calcic alkaline water.

Assays 1 and 2 signify that the public water supply of Greenleaf has high temporary hardness. The water of the city of Hanover is remarkably hard, as assays 3 and 4 indicate. The difference in sulphates in these two tests is noteworthy. Assays 5, 6, 7, and 8 are tests of several wells in Washington, all of which are proven to be very hard, though that of which assay 6 is a test is considerably softer than the others.

Table 96.—*Analyses and assays of underground waters from Washington County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | .......... | Greenleaf, 6 wells...... | 55-65 | Missouri Pacific Ry. | 26 | 1 | 81 | 28 | 26 | 180 | 54 | 15 | 82 | 493 |
| 2 | .......... | Haddam, well ........ | 65 | Chicago, Burlington & Quincy R. R. | ... | [b]38 | 213 | 30 | 81 | 355 | 187 | 31 | .... | .... |
| 3 | 1905. Jan. 25 | Washington, city waterworks well. | 61 | Dearborn Laboratories. | 24 | 1.5 | 54 | 16 | 33 | 109 | 56 | 27 | .... | 325 |
| 4 | ...do..... | Washington, well at plant of Hoerman Bros. Manufacturing Co.[c] | 58 | .....do............. | 85 | 7.1 | 146 | 47 | 83 | 178 | 383 | 31 | .... | 970 |

[a] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 321.
[b] $SiO_2+Fe_2O_3+Al_2O_3$.
[c] Analysis furnished by Hoerman Bros. Manufacturing Co.

TABLE 96.—*Analyses and assays of underground waters from Washington County*—Continued.

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| | 1907. | | | | | | | |
| 1 | Feb. 20 | Greenleaf, city waterworks, 6 wells | 55-65 | Tr. | 0.0 | 358 | 47 | 20 |
| 2 | Oct. 10 | Greenleaf, city waterworks, 3 wells | 55-65 | 0.0 | .0 | 350 | Trace. | 20 |
| 3 | Feb. 18 | Hanover, city waterworks well | 36 | Tr. | .0 | 394 | 578 | 20 |
| 4 | Oct. 10 | ....do | 36 | .0 | .0 | 394 | 313 | 20 |
| 5 | Feb. 19 | Washington, city waterworks well | 61 | Tr. | .0 | 224 | 626 | 45 |
| 6 | Feb. 20 | Washington, well of Mr. Stackpole | 33 | Tr. | .0 | 302 | 91 | 40 |
| 7 | Feb. 19 | Washington, well at plant of Hoerman Bros. Manufacturing Co | 58 | Tr. | .0 | 268 | 626 | 30 |
| 8 | ...do | Washington, well on north bank of Mill Creek of Hoerman Bros. Manufacturing Co | 26 | Tr. | .0 | 371 | 276 | 14 |

## WICHITA COUNTY.

Wichita County is in west-central Kansas, on the High Plains, between the valley of Arkansas and Smoky Hill rivers. The surface is heavily covered by Tertiary deposits, which are probably underlain throughout by the Niobrara formation and possibly, in the northwest corner of the county, by a small amount of Pierre shale. Beneath the Niobrara formation, here 300 to 400 feet thick, is the Benton shale, about 400 feet thick, resting on Dakota sandstone, the formations all dipping gently to the northeast. The Dakota sandstone lies from 800 to 1,100 feet below the surface, its depth increasing gradually from southeast to northwest. It contains water, but the results of the well at Horace, in the adjoining county (Greeley), indicate that the head of this water is sufficient to bring it only within 700 feet of the surface, so that it does not promise to have economic value.

The principal water supplies in the county are obtained from the coarse beds in the lower portions of the Tertiary deposits, at depths ranging from 100 to 300 feet. Some of the wells have been bored into the underlying shales, but these yield no water of any consequence.[1]

The two analyses in Table 97 indicate calcic alkaline waters. Assays 1 and 3 denote soft waters, and assay 2 represents a water that is low in bicarbonates and chlorides but which carries a rather large amount of sulphates.

[1] Abstracted from Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 321.

TABLE 97.—*Analyses and assays of underground waters from Wichita County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | |
| 1 | .......... | Coronado, 2 wells.... | 135, 143 | Missouri Pacific Ry. | 58 | 2 | 56 | 17 | 24 | 75 | 58 | 8.4 | 12 | 311 |
| 2 | .......... | Selkirk, 2 wells...... | 154 | ......do.............. | 46 | 1.9 | 44 | 18 | 16 | 99 | 33 | 11 | 17 | 285 |

| No. | Date. | Source. | Depth (feet). | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | |
| 1 | 1907. Dec. 14 | Leoti, well of Frank Campbell.......... | 86 | 0.0 | 0.0 | 180 | Trace. | 20 |
| 2 | ...do..... | Leoti, well at rear of Font's Mercantile Co........................................ | ........ | .0 | .0 | 180 | 65 | 24 |
| 3 | ...do..... | Leoti, well at C. E. D. Whittaker's livery barn.................................. | 80–90 | .0 | .0 | 185 | Trace. | 15 |

## WILSON COUNTY.

Wilson County is underlain by Pennsylvanian rocks, which yield hard waters.

Analysis 1, Table 98, is a test of a ferromanganese well water and analysis 2 of a highly saline well water at Fredonia.

TABLE 98.—*Analyses of underground waters from Wilson County.*

[Parts per million.]

| No. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Coyville, well of Jacob Killion. [a] [b] | ...... | E. H. S. Bailey and F. B. Porter. | 24 | 12 | 17 | 7.7 | 26 | 157 | .... | 39 |
| 2 | Fredonia, Hudson well [a] | [c]1,175 | E. H. S. Bailey and H. E. Davies. | 43 | 56 | 1,425 | 2,844 | 2,791 | 150 | 40 | 49,285 |

[a] Kansas Univ. Geol. Survey, vol. 7.
[b] Mn, 20.
[c] The salt water is encountered at 400 feet. Br, 79; I, 8.4.

## WOODSON COUNTY.

As Woodson County is underlain by Pennsylvanian rocks, the prospect of finding soft water is poor.

The only analysis presented in Table 99 is of a brine well. The assays are all tests of water at Yates Center. Of these assays, 1 and 4 show soft waters; 2 and 3 indicate very hard ones.

TABLE 99.—*Analysis and assays of underground waters from Woodson County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSIS. | | | | | | | | | | |
| 1 | .......... | Piqua, brine well[a].. | 171 | E. H. S. Bailey.... | Tr. | Tr. | 173 | 109 | (Na) 4,540; (K) 170 | 985 | 82 | 7,127 |

| No. | Date. | Source. | Depth (feet). | Analyst. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|---|---|
| | | ASSAYS. | | | | | | | |
| 1 | 1905. July 24 | Yates Center, well 4 miles south and 2 miles east of city. | 22 | E. Bartow.. | Tr. | 0.0 | 53 | 0.0 | 39 |
| 2 | ...do..... | Yates Center, well 6 miles east of city.[b] | 25 | .....do....... | 0.0 | .0 | 575 | ...... | 258 |
| 3 | July 25 | Yates Center, well.................. | 40 | .....do....... | .0 | .0 | 97 | 154 | 169 |
| 4 | July 24 | Yates Center, spring in southeastern part of city. | ...... | .....do....... | .0 | .0 | 58 | Tr. | 16 |

[a] Kansas Univ. Geol. Survey, vol. 7.
[b] On second bottom of Cherry Creek. $SO_4$ greater than 626.

## WYANDOTTE COUNTY.

Wyandotte County is underlain by Pennsylvanian rocks which may be expected to yield hard waters; it is possible, however, there may be glacial deposits that yield soft waters.

Table 100 presents all the analyses of ground waters that were tested. All these analyses show very hard waters except analysis 13, which denotes a soft water. Calcic alkaline waters are shown by analyses 1, 2, 3, 9, 12, 13, and 14. Calcic magnesic alkaline waters are shown by analyses 10, 11, and 15, while calcic saline waters are shown by analyses 4, 5, 6, 7, and 8. All the waters which were tested for iron show its presence in considerable amounts. The only assay is of the public water supply of Argentine, which is shown to be very hard and to contain a notable quantity of iron. In this latter respect it is like the wells of the public water supply of Lawrence and like those of other cities that derive their water supplies from the fluviatile deposits of the Kansas.

TABLE 100.—*Analyses and assay of underground waters from Wyandotte County.*

[Parts per million.]

| No. | Date. | Source. | Depth (feet). | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ANALYSES. | | | | | | | | | | | | | |
| 1 | 1899. May 9 | Argentine, Atchison, Topeka & Santa Fe Ry. well. | | Atchison, Topeka & Santa Fe Ry. | | 24 | 251 | 18 | 27 | 228 | | 286 | 57 | 157 | 1,058 |
| 2 | 1900. Oct. 20 | Argentine, No. 1 test hole; water stands at 14 feet. | | do. | | 18 | 182 | 28 | 54 | 232 | | 182 | 79 | 118 | 900 |
| 3 | do. | Argentine, test hole 20 feet below surface. | | do. | | 4.7 | 248 | 28 | 6.1 | 239 | | 232 | 76 | 122 | 957 |
| 4 | do. | Argentine, test hole 26 feet below surface. | | do. | | 7.2 | 217 | 13 | 42 | 148 | | 309 | 83 | 113 | 936 |
| 5 | Sept. 28 | Argentine, No. 1 test hole at Kansas River Crib, 10 feet below surface. | | do. | | | 206 | 27 | 101 | 196 | | 294 | 150 | 140 | 1,130 |
| 6 | do. | Argentine, No. 2 test hole at Kansas River Crib, 12 feet below surface. | | do. | | | 251 | 9.4 | 75 | 212 | | 342 | 84 | 106 | 1,078 |
| 7 | do. | Argentine, No. 3 test hole at Kansas River Crib, 20 feet below surface. | | do. | | | 228 | 16 | 32 | 191 | | 290 | 60 | 79 | 895 |
| 8 | do. | Argentine, No. 3 test hole at Kansas River Crib, 26 feet below surface. | | do. | | | 228 | 12 | 37 | 192 | | 300 | 49 | 80 | 893 |
| 9 | 1902. June 7 | Argentine, well, public supply | 58 | do. | 31 | | 203 | 23 | 32 | 222 | | 244 | 33 | 166 | 950 |
| 10 | 1903. Mar. 28 | Argentine, surface wells, samples taken during continuous pumping. | | do. | 19 | | 58 | 16 | 28 | 99 | | 73 | 21 | 44 | 356 |
| 11 | 1902. May 27 | Argentine, points in Kansas River bottom. | | do. | | | 92 | 19 | 16 | 177 | | 38 | 7.3 | 62 | 411 |
| 12 | 1908. Sept. | Armourdale, well | 62 | Chicago, Rock Island & Pacific Ry. | | *a* 55 | 228 | 5.1 | 54 | 247 | | 200 | 67 | | 856 |
| 13 | 1908. Mar. 9 | Edwardsville, spring 160 feet from pump house. | | Union Pacific R. R. | 24 | 5.5 | 76 | 2.6 | 22 | 110 | | 24 | 29 | | 296 |
| 14 | 1907. Feb. 26 | Kansas City, samples from 4 driven wells of Griffin Wheel Co. | 20 | Kennicott Water Softener Co. | 34 | .7 | 159 | 19 | 2 | 211 | | 104 | 15 | | |
| 15 | 1905. Mar. 3 | Kansas City, well of Wulf's Home Steam Laundry. | | do. | | .5 | 52 | 18 | 29 | 78 | | 79 | 18 | | |
| | | ASSAY. | | | | | | | | | | | | | |
| 1 | 1908. Jan. 23 | Argentine, well, public supply | 65 | | | 14 | | | | .0 | 416 | 286 | 44 | | |

*a* $SiO_2+Fe_2O_3+Al_2O_3$.

# SURFACE WATERS.

## GENERAL FEATURES OF DRAINAGE.

The surface waters of Kansas reach the ocean through the Mississippi. The streams of the northern and eastern parts of the State enter the Mississippi by way of Missouri River, which unites with the main stream at a point 15 miles above St. Louis; those of the southern part reach it through Arkansas River at the eastern edge of Desha County, Ark. Kansas River—commonly called the Kaw—discharges into Missouri River at Kansas City, Mo.; it receives the drainage from the northern two-fifths of the State. Osage River carries the run-off of a small area in the eastern part of the State, the waters which enter it in Kansas being merely its fountain head. At the eastern edge of Linn County, the Osage crosses into Missouri, where the main portion of its drainage area lies and where it empties into Missouri River, 12 miles east of Jefferson City. Arkansas River with its tributaries, chief among which are Cimarron, Medicine Lodge, Chikaskia, Caney, Verdigris, Neosho, and Spring rivers, drain the western part of the State.

## MISSOURI RIVER DRAINAGE BASIN.

### Missouri River Above Kansas City.

#### DESCRIPTION.

Missouri River forms the northeastern boundary of Kansas to Kansas City and receives the drainage from somewhat more than half of the State; the southern part of the State drains to the Arkansas.

With the exception of the Nemaha, which drains a small area lying close to the northern boundary of the State, the Missouri receives in Kansas but one important tributary—the Kansas or Kaw—but south of the Kansas is a considerable area drained by the Osage, locally called Marais des Cygnes River, which reaches the main stream near Osage, Mo.

The Missouri itself is utilized in Kansas chiefly as a place of disposal for the sewage of the cities along its banks but also as a source of drinking water. At Kansas City, Kans., its discharge varies within rather wide limits, as shown by Table 101.

TABLE 101.—*Monthly discharge of Missouri River at Kansas City, Kans., for period April 1 to December 31, 1905 (inclusive).*

[Drainage area, 492,000 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| April | 84,800 | 33,600 | 48,990 |
| May | 138.300 | 44,700 | 81,170 |
| June | 148,800 | 73,700 | 111,800 |
| July | 236,000 | 91,550 | 150,800 |
| August | 105,800 | 45,150 | 77,740 |
| September | 168,000 | 30,700 | 71,000 |
| October | 49,680 | 28,250 | 35,560 |
| November | 54,500 | 30,350 | 38,520 |
| December | 42,450 | 16,250 | 25,750 |
| The period | 236,000 | 16,250 | .......... |

Nemaha River enters the Missouri near Rulo, Nebr., a little north of the Kansas-Nebraska State line. The South Fork of this stream drains Nemaha County, Kans.

## QUALITY OF WATER.

Samples of water were collected daily from Missouri River near Kansas City, Kans.,[1] from October 4, 1906, to October 21, 1907. As described on page 11 of this report, samples for ten consecutive days were combined and the composite was analyzed. The results of these analyses are presented in Table 104.

This table shows that in general the bicarbonates are numerically in excess of the sulphates. Considered also in terms of their chemical equivalents, it is found that though the bicarbonates predominate over the sulphates during the larger part of the year, the sulphates are in excess of the bicarbonates in the period from April 15 to June 23. As calcium and sulphates are high, and magnesium is present in moderate amount, the permanent hardness is marked, and as the bicarbonates are rather low, the temporary hardness of the water is moderate. The chlorides are low. The total dissolved solids rise rather regularly and normally as the river falls, for at low stages the river carries considerable ground water, and the water is therefore more highly mineralized than it is when rain water constitutes a large proportion of the flow. The turbidity and suspended matter are very high, excepting the composite sample taken February 3 to 12. The coefficient of fineness varies considerably, but is always high, indicating that the suspended matter is coarse.

As observations of river stage were taken at Kansas City, Mo., below the mouth of the Kansas, during the period in which samples were collected for analysis, it was possible to estimate the amount of denudation accomplished by the river above this point. From these

[1] Above the mouth of Kansas River.

estimates it appears that during the time that the investigation was in progress the Missouri carried away in suspension an average of 567,500 tons and in solution 102,000 tons every 24 hours.

Tests were made of the waters of several Kansas streams that empty into Missouri River above the Kansas, and the results appear in assays 61–65, Table 102. The water of South Branch of Nemaha River at Seneca (assay 61) is soft. The water of Walnut Creek at Padonia (assay 62) has low temporary and marked permanent hardness. Assay 63 represents a test of Nemaha River in flood stage. Wolf Creek at Fanning (assay 64) is soft. Three Mile Creek at Leavenworth (assay 65, Table 102) has very marked permanent hardness. The character of several miscellaneous samples of Missouri River water is shown by Table 105.

Below the mouth of the Kansas, northwest of Independence, Jackson County, Mo., Big Blue River[a] empties into the Missouri.

A test of the water of this river at Mastin, Kans. (analysis 60, Table 103), shows low temporary and permanent hardness.

TABLE 102.—*Assays of water of tributaries of Kansas River and of those of Missouri River between the mouths of Nemaha River and Kansas River.*

[Parts per million.]

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|
| | 1907. | | | | | | |
| 1 | Sept. 23 | North Fork of Smoky Hill River, southwest of Winona | Tr. | 0.0 | 272 | 406 | 30 |
| 2 | ...do..... | Smoky Hill River at Russell Springs | 0.0 | 12 | 88 | 238 | 41 |
| 3 | Dec. 13 | Ladder Creek at Hoppers Dam, 7 miles northwest of Scott City | .0 | 12 | 317 | 42 | 40 |
| 4 | Sept. 21 | Castle Hill Creek at Gove | .0 | 11 | 77 | 104 | 30 |
| 5 | Sept. 20 | Big Creek at Ellis | .0 | .0 | 218 | Trace. | 15 |
| 6 | Sept. 19 | Big Creek at Hays | .0 | .0 | 245 | Trace. | 19 |
| 7 | Sept. 16 | Smoky Hill River at Ellsworth | Tr. | .0 | 232 | 362 | 461 |
| 8 | Sept. 18 | Saline River above Salt Creek north of Russell | .0 | .0 | 257 | 362 | 469 |
| 9 | ...do..... | Salt Creek north of Russell[b] | ..... | ..... | ..... | ..... | 3,270 |
| 10 | ...do..... | Saline River below Salt Creek north of Russell | .0 | 12 | 240 | 362 | 670 |
| 11 | Sept. 9 | West Fork of Wolf Creek at Lucas | .0 | 18 | 400 | 574 | 2,188 |
| 12 | Sept. 1 | Gypsum Creek southwest of Solomon | .0 | .0 | 188 | 100 | 19 |
| 13 | Sept. 5 | Deer Creek at Missouri Pacific Ry. bridge, Kirwin | .0 | .0 | 211 | 38 | 14 |
| 14 | ...do..... | Beaver Creek at Missouri Pacific Ry. bridge, Gaylord | .0 | .0 | 263 | 90 | 24 |
| 15 | ...do..... | North Fork of Solomon River, 30 rods above South Fork, south of Cawker | .0 | .0 | 207 | 58 | 14 |
| 16 | Sept. 28 | South Fork of Solomon River at Morland | .0 | 12 | 269 | Trace. | 10 |
| 17 | Sept. 8 | South Fork of Solomon River at ford west of waterworks, Stockton | .0 | 12 | 180 | 112 | 14 |
| 18 | Sept. 5 | South Fork of Solomon River, 60 rods above North Fork, south of Cawker | .0 | .0 | 211 | 97 | 19 |
| 19 | Sept. 2 | Pipe Creek at Atchison, Topeka & Santa Fe Ry. bridge, Minneapolis | .0 | .0 | 163 | Trace. | 14 |
| 20 | ...do..... | Salt Creek at Atchison, Topeka & Santa Fe Ry. bridge, west of Minneapolis | .0 | .0 | 363 | 287 | 808 |
| 21 | ...do..... | Solomon River at Solomon | .0 | 12 | 274 | 176 | 214 |
| 22 | Aug. 2 | Abilene (Mud) Creek at Abilene | .0 | .0 | 278 | 574 | 35 |
| 23 | ...do..... | Turkey Creek at road bridge south of Abilene | .0 | .0 | 258 | (c) | 40 |
| 24 | Aug. 1 | Chapman Creek at Union Pacific Ry. bridge, Chapman | .0 | 12 | 202 | 389 | 35 |
| 25 | Aug. 12 | Lime Creek at Herington | .0 | 12 | 333 | 59 | 14 |
| 26 | Aug. 1 | Lyons Creek at Missouri, Kansas & Texas Ry. bridge, Wreford | .0 | 12 | 336 | 79 | 20 |

[a] Not to be confused with the river of the same name that flows into Kansas River at Manhattan.
[b] By F. W. Bushong.
[c] $SO_4$ greater than 626.

Table 102.—*Assays of water of tributaries of Kansas River and of those of Missouri River between the mouths of Nemaha River and Kansas River*—Continued.

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|
| | 1907. | | | | | | |
| 27 | Oct. 3 | South Fork of Republican River at St. Francis | 0.0 | 12 | 210 | Trace. | 15 |
| 28 | Oct. 2 | Beaver Creek at Cedar Bluffs | .0 | 0.0 | 227 | Trace. | 20 |
| 29 | Feb. 22 | White Rock Creek at Republic | Tr. | .0 | 313 | 160 | 20 |
| 30 | Feb. 25 | Buffalo Creek at road bridge, Yuma | 1.5 | 11 | 307 | 256 | 859 |
| 31 | Feb. 13 | Wild Cat Creek at Manhattan[a] | Tr. | .0 | 301 | Trace. | 14 |
| 32 | Feb. 18 | Spring Creek at Union Pacific Ry. culvert, Marysville | Tr. | .0 | 156 | Trace. | 10 |
| 33 | Feb. 15 | Big Blue River above Little Blue River, northwest of Blue Rapids | Tr. | .0 | 163 | 36 | 20 |
| 34 | Feb. 19 | Mill Creek at dam of Eureka Mills, Washington | Tr. | .0 | 180 | 47 | 20 |
| 35 | Oct. 10 | Little Blue River at Hanover | .0 | .0 | 158 | Trace. | 30 |
| 36 | Feb. 15 | Little Blue River at dam of Blue Valley Gypsum Co., Blue Rapids | .0 | .0 | 138 | 53 | 19 |
| 37 | Feb. 16 | Vermilion Creek,[b] Frankfort | Tr. | .0 | 161 | 42 | 10 |
| 38 | ...do..... | Black Vermilion River at Missouri Pacific Ry. bridge, Frankfort | Tr. | .0 | 133 | 49 | 10 |
| 39 | Feb. 14 | Fancy Creek at Union Pacific Ry. bridge, Randolph | .0 | .0 | 128 | 44 | 10 |
| 40 | July 24 | Vermilion River at road bridge 5 miles east of Wamego | .0 | .0 | 166 | Trace. | 10 |
| 41 | Aug. 14 | Mill Creek at Atchison, Topeka & Santa Fe Ry. bridge, Alma | .0 | .0 | 295 | 90 | 14 |
| 42 | Aug. 27 | Big Soldier Creek at park, North Topeka | .0 | .0 | 316 | Trace. | 19 |
| 43 | ...do.... | Shonganunga Creek at Lake Street bridge, Topeka | .0 | .0 | 215 | 97 | 34 |
| 44 | July 16 | Little Delaware River at Horton | .0 | .0 | 161 | 62 | 20 |
| 45 | July 15 | Elk Creek north of Campbell College, Holton | .0 | .0 | 313 | Trace. | 25 |
| 46 | (c) | South Fork Sweezy Creek, Lakeview | .0 | .0 | 243 | Trace. | 10 |
| 47 | (c) | Sweezy Creek, Lakeview | .0 | .0 | 271 | 46 | 15 |
| 48 | (c) | Lake, Lakeview | .0 | .0 | 123 | Trace. | 10 |
| 49 | (c) | Martin Creek, Lakeview | .0 | .0 | 304 | Trace. | 10 |
| 50 | June 16 | Mud Creek, 2¾ miles north of Lawrence | .0 | .0 | 307 | Trace. | 10 |
| 51 | (c) | Rock Creek near mouth, southwest of Lawrence | .0 | .0 | 316 | 40 | 10 |
| 52 | (c) | Washington Creek near mouth, southwest of Lawrence | .0 | .0 | 335 | Trace. | 12 |
| 53 | (d) | Wakarusa Creek at bridge, southwest of Lawrence | .0 | .0 | 316 | 48 | 20 |
| 54 | Nov. 3 | Wakarusa Creek south of Lawrence | .0 | .0 | 369 | Trace. | 30 |
| 55 | July 9 | Big Stranger Creek above Nine Mile Creek at Linwood | .0 | .0 | 208 | Trace. | 10 |
| 56 | ...do..... | Nine Mile Creek at road bridge, Linwood | .0 | .0 | 307 | Trace. | 10 |
| 57 | ...do..... | Big Stranger Creek at Union Pacific Ry. bridge, Linwood | .0 | .0 | 219 | Trace. | 10 |
| 58 | Jan. 4 | Cedar Creek west of Olathe | .0 | .0 | 144 | 106 | 14 |
| 59 | ...do..... | Railroad pond on Mill Creek, Olathe | .0 | .0 | 93 | 35 | ........ |
| 60 | Jan. 5 | Mill Creek at Holliday | .0 | .0 | 254 | 73 | 30 |
| 61 | July 22 | South Branch of Nemaha River at Seneca | .0 | .0 | 273 | Trace. | 14 |
| 62 | July 20 | Walnut Creek at Padonia | .0 | .0 | 197 | 42 | 24 |
| 63 | ...do..... | Nemaha River,[e] 3 miles south of Falls City, Nebr. | ...... | .0 | 66 | Trace. | 20 |
| 64 | July 17 | Wolf Creek at Fanning | .0 | .0 | 149 | Trace. | 14 |
| 65 | July 12 | Three Mile Creek at Cherokee and Broadway streets, Leavenworth | .0 | .0 | 234 | 208 | 100 |

[a] Above sewer outfall of Kansas Agricultural College.
[b] Local name of west branch of Black Vermilion River.
[c] Assay by Edward Bartow, June 3, 1905.
[d] Assay by Edward Bartow, June 6, 1905.
[e] In flood.

Note.—Trace in the sulphate column means less than 35 parts per million; trace in the iron column means less than 0.5 part per million.

TABLE 103.—*Analyses of water from Kansas River and its tributaries.*

[Parts per million.]

| No. | Date. | Source. | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$).[a] | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Organic and volatile. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mar. 18, 1908 | South Fork Smoky Hill River, at Somena. | Union Pacific R. R. | 21 | 1.4 | 95 | 15 | 35 | 119 | ........ | 144 | 4.4 | 19 | ........ | 454 |
| 2 | Mar. 16, 1908 | North Fork Smoky Hill River at McAllaster. | ....do | 35 | 2.4 | 101 | 32 | 26 | 138 | ........ | 184 | ........ | 15 | ........ | 535 |
| 3 | Mar. 31, 1908 | Big Creek at Ellis | ....do | 35 | 2 | 77 | 20 | 23 | 170 | ........ | 18 | ........ | 18 | ........ | 365 |
| 4 | Nov. 21, 1901 | Smoky Hill River at Ellsworth. | Dearborn laboratories | 25 | 2.7 | 103 | 30 | 418 | 612 | ........ | 406 | ........ | ........ | ........ | ........ |
| 5 | ........ | Smoky Hill River at Salina. | Missouri Pacific Ry | 32 | 1.5 | 170 | 35 | 40 | 246 | ........ | 188 | ........ | 36 | 50 | 800 |
| 6 | Winter 1892-3 | Smoky Hill River below Salina | E. H. S. Bailey | 21 | 4.9 | 142 | 27 | b 182 | b 164 | ........ | 251 | ........ | 229 | ........ | 1,017 |
| 7 | ....do | Saline River above New Cambria. | ....do | 24 | 3.5 | 140 | 47 | b 647 | b 340 | ........ | 420 | ........ | 858 | ........ | 2,323 |
| 8 | ........ | Gypsum Creek at Gypsum City. | Missouri Pacific Ry | 23 | 3.5 | 67 | 25 | 55 | 145 | ........ | 134 | ........ | 8.1 | 22 | 484 |
| 9 | ........ | Elm Creek at Lenora | ....do | 47 | 1.4 | 74 | 16 | 8.9 | 157 | ........ | 0 | ........ | 7.6 | 27 | 341 |
| 10 | Sept. 30, 1902 | Solomon River at Minneapolis. | Atchison, Topeka & Santa Fe Ry. | 28 | Tr. | 55 | 11 | 39 | 91 | ........ | 53 | ........ | 42 | ........ | ........ |
| 11 | Winter 1892-3 | Solomon River above Solomon. | E. H. S. Bailey | 40 | 3.5 | 128 | 24 | b 226 | b 156 | ........ | 257 | ........ | 270 | ........ | 1,105 |
| 12 | Sept. 19, 1902 | Pond at Manchester | Atchison, Topeka & Santa Fe Ry. | 50 | 3.6 | 11 | 2 | 16 | 28 | ........ | 13 | ........ | 6 | ........ | ........ |
| 13 | ........ | Turkey Creek at Swayne | Missouri Pacific Ry | 40 | 3.5 | 517 | 90 | 78 | 133 | ........ | 1,504 | ........ | 31 | 80 | 2,477 |
| 14 | Sept. 27, 1902 | Lyons Creek at Jacobs | Atchison, Topeka & Santa Fe Ry. | 31 | Tr. | 128 | 37 | 34 | 218 | ........ | 138 | ........ | 24 | ........ | ........ |
| 15 | ........ | Chism (Lime ?) Creek at Herington. | Missouri Pacific Ry | 23 | 1 | 105 | 57 | 52 | 276 | ........ | 141 | ........ | 5.6 | ........ | 661 |
| 16 | Dec. 8, 1902 | Lime Creek at Herington | Chicago, Rock Island & Pacific Ry. Co. | 14 | 2.4 | 49 | 23 | 13 | 104 | ........ | 43 | ........ | 19 | ........ | ........ |
| 17 | Oct. 3, 1907 | Arikaree River at Benkelman, Nebr. | F. W. Bushong | 47 | .04 | 103 | 42 | 101 | 0 | 270 | 337 | Tr. | 17 | ........ | 760 |
| 18 | Sept. 1908 | Pond at Belleville | Chicago, Rock Island & Pacific Ry. | c 19 | ........ | 24 | 12 | 59 | 51 | ........ | 98 | ........ | 37 | ........ | 300 |
| 19 | Winter 1892-3 | Republican River above Junction City. | E. H. S. Bailey | 64 | 5.3 | 86 | 18 | b 72 | b 163 | ........ | 75 | ........ | 55 | ........ | 554 |
| 20 | 1909 | Mill Creek at Washington | Chicago, Burlington & Quincy R. R. | ........ | ........ | 188 | 22 | 67 | 359 | ........ | 51 | ........ | 65 | ........ | ........ |
| 21 | Winter 1892-3 | Big Blue River above Manhattan. | E. H. S. Bailey | 37 | 5 | 82 | 22 | b 34 | b 154 | ........ | 78 | ........ | 28 | ........ | 436 |
| 22 | Mar. 5, 1908 | Big Blue River at Manhattan. | Union Pacific R. R. | 66 | 10 | 57 | 8.6 | 25 | 92 | ........ | 25 | ........ | 38 | ........ | 326 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | Nov. 15, 1902 | Mill Creek at Alma | Atchison, Topeka & Santa Fe Ry. | 5.3 | 1.7 | 102 | 27 | 5.5 | 186 | ........ | 53 | ........ | 12 | ........ | ........ |
| 24 | Sept. 1908 | Mill Creek at McFarland | Chicago, Rock Island & Pacific Ry. | 5. c 3 | ........ | 94 | 23 | 13 | 139 | ........ | 97 | ........ | 17 | ........ | 386 |
| 25 | Winter 1892–3 | Kansas River above Topeka | E. H. S. Bailey | | 3.9 | 115 | 28 | b 117 | b 177 | ........ | 145 | ........ | 144 | ........ | 771 |
| 26 | Dec. 1902 | do | do | d 111 | ........ | 110 | 26 | 86 | ........ | ........ | 84 | ........ | 100 | ........ | ........ |
| 27 | do | Kansas River below Topeka | do | e 142 | ........ | 73 | 47 | 87 | ........ | ........ | 79 | ........ | 97 | ........ | ........ |
| 28 | Jan. 1903 | Kansas River above Topeka | do | f 57 | ........ | 122 | 26 | 87 | ........ | ........ | 109 | ........ | 91 | ........ | ........ |
| 29 | do | Kansas River below Topeka | do | g 424 | ........ | 120 | 27 | 85 | ........ | ........ | 107 | ........ | 90 | ........ | ........ |
| 30 | Feb. 1903 | Kansas River above Topeka | do | e 135 | ........ | 104 | 23 | 82 | ........ | ........ | 102 | ........ | 87 | ........ | ........ |
| 31 | do | Kansas River below Topeka | do | h 201 | ........ | 106 | 22 | 90 | ........ | ........ | 109 | ........ | 92 | ........ | ........ |
| 32 | Feb. 7, 1898 | Kansas River at shops, Topeka. | Atchison, Topeka & Santa Fe Ry. | 43 | ........ | 103 | 16 | 111 | 176 | ........ | 112 | ........ | 137 | 113 | 808 |
| 33 | Aug. 31, 1898 | Kansas River at Topeka | do | ........ | ........ | 76 | 18 | 52 | 125 | ........ | 82 | ........ | 58 | 75 | 490 |
| 34 | Oct. 30, 1899 | Kansas River at Topeka, low stage. | do | 24 | ........ | 109 | 22 | 154 | 218 | ........ | 124 | ........ | 145 | 123 | ........ |
| 35 | July 30, 1900 | Kansas River at Topeka | do | ........ | ........ | 36 | 6.3 | 15 | 74 | ........ | 13 | ........ | 23 | 44 | 197 |
| 36 | ........ | Kansas River at South Topeka. | Missouri Pacific Ry | 34 | 1.4 | 66 | 13 | 53 | 107 | ........ | 69 | ........ | 61 | 23 | 428 |
| 37 | Dec. 1903 | Creek at Horton | Chicago, Rock Island & Pacific Ry. | 2.6 | Tr. | 43 | 16 | .8 | 96 | ........ | 6.6 | ........ | 6.1 | ........ | ........ |
| 38 | ........ | Delaware River at Muscotah. | Missouri Pacific Ry | 13 | 1.2 | 122 | 28 | 30 | 202 | ........ | 118 | ........ | 17 | 28 | 568 |
| 39 | Sept. 1908 | Elk Creek at Holton | Chicago, Rock Island & Pacific Ry. | c 13 | ........ | 102 | 27 | 27 | 177 | ........ | 80 | ........ | 34 | ........ | 449 |
| 40 | Nov. 15, 1902 | Delaware River at Valley Falls. | Atchison, Topeka & Santa Fe Ry. | 13 | .8 | 80 | 15 | 16 | 148 | ........ | 26 | ........ | 18 | ........ | ........ |
| 41 | Dec. 1893 | Delaware River at Perry | J. E. Curry | 13 | 3.7 | 89 | 21 | b 18 | b 172 | ........ | 44 | ........ | 2.3 | ........ | 396 |
| 42 | Mar. 3, 1908 | do | Union Pacific R. R | 41 | 10 | 34 | 10 | 47 | 82 | ........ | 77 | ........ | 9.1 | ........ | 317 |
| 43 | Winter 1892–3 | Kansas River above Lawrence. | E. H. S. Bailey | 30 | 3.4 | 112 | 27 | b 121 | b 189 | ........ | 134 | ........ | 144 | ........ | 762 |
| 44 | Mar. 4, 1908 | Kansas River at Lawrence | Union Pacific R. R | 30 | 5.6 | 68 | 44 | 67 | 177 | ........ | 79 | ........ | 84 | ........ | 557 |
| 45 | ........ | Wakarusa Creek at Richland. | Missouri Pacific Ry | 12 | 1.2 | 85 | 17 | 18 | 142 | ........ | 53 | ........ | 21 | 25 | 376 |
| 46 | Nov. 15, 1902 | Wakarusa Creek at Wakarusa. | Atchison, Topeka & Santa Fe Ry. | 22 | 1.7 | 33 | 7 | 3.4 | 55 | ........ | 20 | ........ | 5.7 | ........ | ........ |
| 47 | June 3, 1908 | Big Stranger Creek at Linwood. | Union Pacific R. R | 26 | 3.8 | 57 | 16 | 17 | 108 | ........ | 41 | ........ | 16 | ........ | 287 |
| 48 | Nov. 15, 1902 | Pond at Olathe | Atchison, Topeka & Santa Fe Ry. | 9 | 2.1 | 46 | 12 | ........ | 59 | ........ | 55 | ........ | 6.2 | ........ | ........ |
| 49 | do | Kansas River at Holliday | do | 32 | Tr. | 54 | 29 | 27 | 119 | ........ | 68 | ........ | 33 | ........ | ........ |
| 50 | Dec. 1902 | Kansas River at Argentine | E. H. S. Bailey | i 169 | ........ | 50 | 56 | 75 | ........ | ........ | 89 | ........ | 88 | ........ | ........ |

a Obtained by computation to ionic form; results originally stated as in hypothetical combinations.
b Calculated.
c $SiO_2+Al_2O_3+Fe_2O_3$.
d Al=11, analysis of unfiltered sample.
e Al=13, analysis of unfiltered sample.
f Al=4.9, analysis of unfiltered sample.
g Al=31, analysis of unfiltered sample.
h Al=18, analysis of unfiltered sample.
i Al=6.7, analysis of unfiltered sample above Kansas City sewers.

TABLE 103.—*Analyses of water from Kansas River and its tributaries*—Continued.

| No. | Date. | Source. | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Organic and volatile. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51 | Jan. 1903 | Kansas River at Argentine | E. H. S. Bailey | a 424 | ...... | 120 | 27 | 84 | ........ | ........ | 107 | ...... | 90 | ........ | ........ |
| 52 | Feb. 1903 | do | do | b 712 | ...... | 97 | 24 | 62 | ........ | ........ | 79 | ...... | 62 | ........ | ........ |
| 53 | May 9, 1899 | do | Atchison, Topeka & Santa Fe Ry. | 31 | 23 | 75 | 14 | 40 | 119 | ........ | 70 | ...... | 43 | 94 | 486 |
| 54 | Nov. 16, 1900 | do | do | ........ | ...... | 71 | 12 | 59 | 119 | ........ | 66 | ...... | 63 | 41 | 431 |
| 55 | May 27, 1902 | do | do | ........ | ...... | 124 | 8 | 77 | 98 | ........ | 94 | ...... | 178 | 113 | 693 |
| 56 | Oct. 29, 1902 | do | do | 34 | .7 | 104 | 16 | 29 | 150 | ........ | 85 | ...... | 36 | ........ | ........ |
| 57 | Sept. 1908 | Kansas River at Armourdale. | Chicago, Rock Island & Pacific Ry. | b 3 | ...... | 88 | 20 | 77 | 135 | ........ | 113 | ...... | 92 | ........ | 528 |
| 58 | Feb. 6, 1904 | Kansas River at Nelson Morris & Co., Kansas City, Kans. | Kennicott Water Softener Co. | 32 | 3 | 127 | 30 | 127 | 198 | ........ | 150 | ...... | 164 | ........ | ........ |
| 59 | July 19, 1899 | Turkey Creek Crane | Atchison, Topeka & Santa Fe Ry. | ........ | ...... | 30 | 9.3 | 72 | 63 | ........ | 134 | ...... | 16 | 79 | 404 |
| 60 | .............. | Big Blue River at Mastin | Missouri Pacific Ry | 17 | 1.3 | 95 | 7.7 | 4.4 | 146 | ........ | 29 | ...... | 5.3 | 19 | 325 |

a Al=31, analysis of unfiltered sample above Kansas City sewers.

b Al=65, analysis of unfiltered sample above Kansas City sewers.

TABLE 104.—*Analyses of water from Missouri River, near Kansas City, Mo.*

[Drainage area 430,300 square miles. Quantities in parts per million.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. | Mean gage height (feet).[a] | Mean discharge (cubic feet per second). | Run-off per square mile (cubic feet per second). | Estimated mean discharge above Kansas River (second-feet). | Suspended matter (1,000 tons per 24 hours). | Dissolved matter (tons per 24 hours). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | | | | | | | |
| Oct. 4 | Oct. 13 | 2,500 | 2,231 | 0.89 | 31 | 0.30 | 60 | 19 | 49 | 0.0 | 198 | 138 | 2.2 | 13 | 419 | 8.5 | 42,900 | 0.087 | 38,900 | 234 | 44,010 |
| Oct. 14 | Oct. 23 | 900 | 942 | 1.05 | 26 | Tr. | 69 | 21 | 40 | .0 | 215 | 154 | .4 | 13 | 438 | 7.2 | 32,100 | .065 | 28,440 | 72 | 33,630 |
| Oct. 24 | Nov. 2 | 1,230 | 1,680 | 1.36 | 33 | .50 | 64 | 21 | ...... | .0 | 217 | 128 | 2.2 | 15 | 426 | 8.7 | 44,700 | .091 | 40,810 | 185 | 46,940 |
| Nov. 3 | Nov. 12 | 1,500 | 1,470 | .98 | 31 | .40 | 69 | 22 | 49 | .0 | 219 | 150 | 2.2 | 13 | 447 | 9.0 | 47,400 | .096 | 42,880 | 170 | 50,750 |
| Nov. 13 | Nov. 22 | 870 | 840 | .97 | 38 | .40 | 75 | 24 | 50 | .0 | 236 | 164 | .9 | 13 | 486 | 8.6 | 43,800 | .089 | 39,460 | 89 | 51,780 |
| Nov. 23 | Dec. 2 | 475 | 577 | 1.21 | 30 | .20 | 77 | 22 | 53 | .0 | 270 | 158 | .4 | 15 | 495 | 7.6 | 35,200 | .072 | 30,510 | 48 | 40,780 |
| Dec. 3 | Dec. 12 | 500 | 547 | 1.09 | 38 | .40 | 77 | 21 | ...... | .0 | 275 | 146 | 1.8 | 17 | 510 | 7.0 | 30,700 | .062 | 26,360 | 39 | 36,300 |
| Dec. 13 | Dec. 22 | 300 | 319 | 1.06 | 30 | .40 | 85 | 27 | 51 | .0 | 307 | 175 | .9 | 20 | 525 | 4.5 | 15,500 | ...... | 11,330 | 10 | 16,060 |
| | 1907. | | | | | | | | | | | | | | | | | | | | |
| Dec. 23 | Jan. 2 | 190 | 222 | 1.17 | 41 | .12 | 91 | 29 | 55 | .0 | 334 | ...... | 1.3 | 22 | 580 | 4.5 | 15,500 | ...... | 10,470 | 6 | 16,400 |
| 1907. | | | | | | | | | | | | | | | | | | | | | |
| Jan. 3 | Jan. 12 | 350 | 374 | 1.07 | 39 | .40 | 78 | 26 | 49 | .0 | 265 | 158 | 2.6 | 18 | 503 | 7.4 | 33,600 | .068 | 29,080 | 29 | 39,490 |
| Jan. 13 | Jan. 22 | 270 | 247 | .91 | 35 | .35 | 79 | 23 | 52 | .0 | 265 | 159 | 3.1 | 18 | 493 | 6.3 | 25,800 | .052 | 21,110 | 14 | 28,100 |
| Jan. 23 | Feb. 2 | 140 | 96 | .69 | 41 | .08 | 90 | 30 | 55 | .0 | 326 | 176 | 2.2 | 23 | 579 | 5.1 | 18,550 | .036 | 13,860 | 4 | 21,670 |
| Feb. 3 | Feb. 12 | 35 | 24 | .68 | 43 | .20 | 84 | 28 | 68 | .0 | 328 | 167 | 2.2 | 24 | 590 | 5.2 | 19,100 | .039 | 15,210 | 1 | 24,230 |
| Feb. 13 | Feb. 22 | 1,020 | 1,316 | 1.29 | 70 | 2.8 | 61 | 22 | 61 | .0 | ...... | ...... | 4.4 | 16 | 454 | 10.2 | 59,000 | .119 | 53,460 | 190 | 65,530 |
| Feb. 23 | Mar. 5 | 1,400 | 1,730 | 1.24 | 74 | .20 | 56 | 17 | 43 | .0 | 156 | ...... | 1.7 | 8.5 | 414 | 13.5 | 96,700 | .196 | 88,130 | 412 | 98,510 |
| Mar. 6 | Mar. 15 | 1,500 | 1,896 | 1.26 | 41 | 1.4 | 52 | 15 | 37 | .0 | 164 | 122 | 3.4 | 9.5 | 392 | 12.0 | 78,300 | .159 | 69,160 | 354 | 73,200 |
| Mar. 16 | Mar. 25 | 3,450 | 2,867 | .83 | 65 | 2.1 | ...... | ...... | 39 | .0 | 164 | 123 | 1.9 | 11 | 435 | 13.5 | 96,700 | .196 | 90,300 | 699 | 106,060 |
| Mar. 26 | Apr. 4 | 2,150 | 2,619 | 1.22 | 55 | 2.1 | ...... | 10 | 41 | .0 | 157 | ...... | 2.5 | 6.3 | 362 | 12.7 | 86,600 | .176 | 81,400 | 576 | 79,560 |
| Apr. 5 | Apr. 14 | 2,800 | 2,826 | 1.01 | 62 | 2.4 | 53 | 15 | 42 | .0 | 168 | 137 | 2.2 | 8.7 | 440 | 13.1 | 91,580 | .186 | 86,550 | 660 | 102,820 |
| Apr. 15 | Apr. 24 | 3,600 | 3,496 | .97 | 41 | .50 | 68 | 11 | 55 | .0 | 162 | 179 | 3.0 | 9.5 | 462 | 13.2 | 92,860 | .189 | 88,340 | 834 | 110,200 |
| Apr. 25 | May 4 | 3,800 | 3,938 | 1.04 | 89 | 1.8 | ...... | 20 | 60 | .0 | ...... | 171 | Tr. | 11 | 549 | 12.0 | 78,300 | .159 | 73,780 | 784 | 109,360 |
| May 5 | May 14 | 2,800 | 2,350 | .84 | 47 | 3.2 | ...... | 16 | 48 | .0 | 160 | 176 | 5.3 | 11 | 478 | 11.3 | 70,500 | .143 | 66,160 | 420 | 85,390 |
| May 15 | May 24 | 1,200 | 1,952 | 1.62 | 49 | 1.2 | 58 | ...... | 43 | .0 | 176 | ...... | 3.5 | 12 | 394 | 10.1 | 58,000 | .118 | 54,000 | 285 | 57,440 |
| May 25 | June 3 | 3,850 | 4,204 | 1.10 | 43 | 1.1 | ...... | 17 | 46 | .0 | 171 | 170 | 3.9 | 14 | 460 | 13.0 | 90,300 | .183 | 85,270 | 968 | 105,900 |
| June 4 | June 13 | 5,350 | 6,611 | 1.24 | 20 | 1.0 | 53 | 14 | 52 | .0 | 161 | 168 | .7 | 8.5 | 424 | 17.7 | 154,560 | .314 | 146,560 | 2,616 | 167,780 |
| June 14 | June 23 | 3,200 | 4,719 | 1.48 | 26 | .10 | 56 | 14 | 56 | .0 | 157 | 168 | 2.6 | 8.4 | 418 | 17.8 | 156,040 | .317 | 148,950 | 1,898 | 168,000 |
| June 24 | July 4 | 4,000 | 3,982 | 1.00 | 25 | 1.2 | 57 | ...... | 45 | .0 | 178 | 131 | 3.5 | 8.8 | 406 | 18.6 | 166,650 | .339 | 161,110 | 1,732 | 176,610 |

[a] Gaging station near Kansas City, Mo., below Kansas River drainage area, 491,800 square miles.

TABLE 104.—*Analyses of water from Missouri River, near Kansas City, Mo.*—Continued.

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron. (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. | Mean gage height (feet). | Mean discharge (cubic feet per second). | Run-off per square mile (cubic feet per second). | Estimated mean discharge above Kansas River (second-feet). | Suspended matter (1,000 tons per 24 hours). | Dissolved matter (tons per 24 hours). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1907. | 1907. | | | | | | | | | | | | | | | | | | | | |
| July 5 | July 14 | 4,400 | 4,676 | 1.06 | 22 | 0.05 | 53 | 10 | 46 | 0.0 | 159 | 143 | 3.7 | 8.3 | 383 | 19.8 | 186,000 | 0.378 | 181,140 | 2,287 | 187,320 |
| July 15 | July 24 | 3,600 | 3,147 | .87 | 24 | .48 | 47 | 13 | 38 | .0 | 157 | 103 | 4.1 | 6.7 | 316 | 22.6 | 229,600 | .467 | 214,230 | 1,820 | 182,780 |
| July 25 | Aug. 3 | 2,000 | 3,458 | 1.73 | 15 | Tr. | 46 | ...... | 37 | .0 | 183 | 101 | 3.4 | 6.0 | 323 | 19.1 | 175,500 | .357 | 167,500 | 1,564 | 146,080 |
| Aug. 4 | Aug. 13 | 2,700 | 3,013 | 1.12 | 22 | .30 | 44 | 12 | 29 | .0 | ........ | 99 | 3.0 | 5.5 | 295 | 16.5 | 137,600 | .280 | 131,880 | 1,074 | 105,040 |
| Aug. 14 | Aug. 23 | 2,400 | 2,651 | 1.12 | 21 | .28 | 44 | 14 | .......... | .0 | 136 | 95 | .9 | 7.0 | 291 | 13.8 | 100,600 | .204 | 95,740 | 685 | 75,220 |
| Aug. 24 | Sept. 2 | 2,000 | 1,677 | .84 | 18 | .05 | 45 | 14 | .......... | .0 | 152 | 92 | 1.3 | ...... | 293 | 11.1 | 68,150 | .138 | 64,490 | 292 | 51,020 |
| Sept. 3 | Sept. 12 | 1,700 | 1,376 | .81 | 20 | .03 | 45 | 12 | 31 | .0 | 155 | 87 | 1.6 | 11 | 307 | 9.9 | 56,000 | .114 | 52,570 | 195 | 43,580 |
| Sept. 13 | Sept. 22 | 1,200 | 878 | .73 | 27 | .33 | 53 | 10 | 38 | .0 | 171 | 105 | 1.8 | 13 | 337 | 8.5 | 42,900 | .087 | 39,930 | 95 | 36,330 |
| Sept. 23 | Oct. 2 | 1,075 | 791 | .74 | 27 | .26 | 53 | 12 | 36 | .0 | 167 | 108 | 1.6 | 13 | 339 | 8.3 | 41,100 | .084 | 37,900 | 81 | 34,690 |
| Oct. 4 | Oct. 13 | 1,100 | 792 | .72 | 26 | 1.0 | 53 | 11 | 43 | *a* Tr. | 171 | 110 | 1.5 | 17 | 349 | 8.6 | 43,800 | .089 | 40,490 | 87 | 38,150 |
| Oct. 14 | Oct. 21 | 1,000 | 829 | .67 | 28 | .28 | 56 | 9.8 | 45 | *a* Tr. | 180 | 120 | 1.3 | 16 | 389 | 7.6 | 35,200 | .072 | 31,660 | 57 | 3,320 |
| | | | | | | | | | | | | | | | | | 2,897,390 | ........ | 2,699,120 | 21,566 | 2,860,030 |
| Mean | | 1,909 | 2,032 | 1.04 | 37 | .73 | 62 | 18 | 44 | .0 | 202 | 135 | 2.2 | 13 | 426 | ...... | .......... | ........ | 71,030 | 567.5 | 102,144 |
| Per cent of anhydrous residue | | ....... | ....... | ....... | 9.0 | .2 | 15.0 | 4.4 | 10.7 | 24.2 | ......... | 32.8 | .5 | 3.2 | ....... | ...... | .......... | ........ | ......... | ....... | ....... |

*a* Abnormal, computed as $HCO_3$ in the average.

NOTE.—Analyses from October 4, 1906, to February 12, 1907, by W. M. Barr; from February 13, to February 22 1907, by H. S. Spaulding; from February 23 to September 12, 1907, by Walton Van Winkle; from September 13 to October 21, 1907, by R. B. Dole, Chase Palmer, and W. D. Collins.

TABLE 105.—*Analyses of water from Missouri River in Kansas.*

[Parts per million.]

| No. | Date. | Source. | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$).[a] | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Nov. 15, 1902 | Missouri River at Atchison. | Atchison, Topeka & Santa Fe Ry. | 20 | 0.9 | 46 | 14 | 35 | 80 | ........ | 89 | ........ | 17 | ........ | ........ |
| 2 | .............. | Missouri River (city waterworks) at Atchison. | Missouri Pacific Ry.... | 27 | 2.9 | 52 | 17 | 30 | 94 | ........ | 84 | ........ | 14 | 20 | 343 |
| 3 | Sept. 8, 1901 | Missouri River at Leavenworth. | Atchison, Topeka & Santa Fe Ry. | ........ | 4.7 | 44 | 7.4 | 36 | 52 | ........ | 116 | ........ | 8.5 | 31 | 303 |
| 4 | Nov. 15, 1902 | .....do.... | .....do.... | 17 | .8 | 47 | 13 | 39 | 81 | ........ | 99 | ........ | 12 | ........ | ........ |
| 5 | May 30, 1908 | Missouri River (city waterworks) at Atchison. | Kennicott Water Softener Co. | 9 | .4 | 47 | 12 | 38 | 60 | ........ | 123 | ........ | 12 | ........ | ........ |
| 6 | July 12, 1901 | Lake at Carr mines, Leavenworth. | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 66 | 15 | 15 | 115 | ........ | 36 | ........ | 23 | 70 | 339 |
| 7 | Jan. 13, 1908 | Missouri River at Lansing... | F. W. Bushong........ | 30 | .1 | 85 | 23 | 56 | 0 | 275 | 119 | 0.7 | 22 | ........ | 436 |
| 8 | Feb. 26, 1907 | Missouri River (city waterworks), Kansas City, Kans. | Kennicott Water Softener Co. | 22 | 3.8 | 49 | 13 | 29 | 72 | ........ | 102 | ........ | 12 | ........ | ........ |
| 9 | Mar. 3, 1908 | .....do.... | Union Pacific Ry...... | 64 | 7.8 | 44 | 14 | 47 | 104 | ........ | 83 | ........ | 7.8 | ........ | 376 |
| 10 | Dec. 12, 1902 | Missouri River at Kansas City, Mo. | Atchison, Topeka & Santa Fe Ry. | 15 | ........ | 62 | 13 | 39 | 112 | ........ | 76 | ........ | 20 | 44 | 392 |
| 11 | Nov. 26, 1900 | Missouri River (Metropolitan waterworks before filtration) at Kansas City, Mo. | .....do.... | ........ | ........ | 46 | 11 | 18 | 61 | ........ | 68 | ........ | 21 | 41 | 270 |
| 12 | June 6, 1908 | Missouri River at Kansas City, Mo. | Archie J. Weith........ | 25 | .88 | 47 | 15 | 45 | ........ | ........ | 93 | 2.5 | 8.7 | ........ | 298 |

[a] Obtained by computation to ionic form; results originally stated as in hypothetical combinations.

## Kansas River System.

### PRINCIPAL RIVERS.

The drainage basin of Kansas River lies between the basins of Platte and Nemaha rivers on the north and Arkansas and Osage rivers on the south. Its entire area is approximately 61,440 square miles, of which 9,459 square miles are in Colorado, 17,455 square miles in Nebraska, and 34,526 square miles are in Kansas. The principal rivers of the system, named in succession from west to east across the State, are the Smoky Hill, the Saline, the Solomon, the Republican, the Kansas, the Big Blue, and the Delaware. Saline and Solomon rivers are tributaries of the Smoky Hill. Kansas River is formed at Junction by the confluence of the Smoky Hill and the Republican. Big Blue and Delaware rivers flow directly into the Kansas. All of the large tributaries of both the Smoky Hill and the Kansas enter those streams from the north; the affluents from the south are all small because the divide that separates Kansas River Basin from the basins of the Arkansas and the Osage runs close to the Smoky Hill and the Kansas. The principal rivers that compose the Kansas River system are described in detail in the following pages.

### SMOKY HILL RIVER BASIN.

#### DESCRIPTION.

Smoky Hill River rises in the eastern part of Colorado in Kit Carson and Cheyenne counties, where its chief upper branches—the North and South Forks—are formed. Flowing in general easterly direction to Logan County, Kans., the two forks unite near McAllaster, from which point the main stream flows southeastward across Wallace, Logan, Gove, Trego, Ellis, Russell, Ellsworth, and McPherson counties to the vicinity of Lindsborg, where it turns northward to Salina and there again turns, taking a northeasterly course and running across Dickinson County into Geary County, where it unites with Republican River to form the Kansas or Kaw. The length of the river from its source to the point of junction is 310 miles, and in this distance the most important tributaries received by the river are Castle Hill Creek, Big Creek, Saline River, and Solomon River. Of these the Saline and Solomon are the most important. They enter the river from the north, but in general their courses parallel the main stream.

The drainage area of the Smoky Hill comprises 20,480 square miles, of which 331 square miles drain to Saline River and 6,882 square miles to the Solomon.

Both the North and South Forks of Smoky Hill River rise in an area of sand, clay, and gravel (Tertiary deposits). South Fork cuts down to the sandstones and shales of the Cretaceous in Cheyenne County, Colo., and the North Fork reaches the Cretaceous in Sherman County, Kans., and the two forks continue in the Cretaceous formations to their confluence. The main stream flows in the Cretaceous rocks to a point near the mouth of Clear Creek, a little east of Kanopolis, where it enters the rocks of the Permian series, in which it runs to the eastern edge of Dickinson County, where it cuts into Pennsylvanian rocks. Neither of the headwater forks of the river is perennial.

In its course through the Cretaceous formations Smoky Hill River varies considerably in volume. In the western part of the State, although rainfall is deficient, the flow of the stream is kept up by seeps and springs from the Tertiary deposits, but in the region where its channel is cut deeper into the Cretaceous formations its flow becomes wholly dependent on the rainfall, for the underground supply from the Tertiary deposits is withdrawn and the Cretaceous formations, with the exception of the Dakota sandstone, are not water bearing. In this region evaporation is intense and at certain seasons of the year exceeds the rainfall so that the river dries up. East of Russell County not only does the rainfall increase, but the stream in its down cutting reaches the water-bearing Dakota sandstone and once more becomes perennial.

The most striking features of Smoky Hill River are its extraordinarily deep channel—deeper, perhaps, than that of any other stream in the State—and its narrow valley. Through a large part of its course in Gove, Trego, and Ellis counties the main uplands on each side of the river are from 300 to 400 feet above the valley of the stream itself. These uplands have been somewhat eroded and have the rounded form characteristic of old age. The great depth of the channel has caused all the lateral tributaries likewise to cut deeper channels, and the country on both sides of the river from 2 to 4 miles back is so hilly that it is difficult to travel parallel with the stream. Farther west, in places where the main part of the bluffs are composed of Tertiary deposits, the country is less rugged and the channel gradually becomes shallower. In Gove and Trego counties, and the western part of Ellis County the rocks are cut in the chalk beds of the Niobrara formation which have yielded to erosion very easily.

The valley of Smoky Hill River is, as a rule, narrow. In but few places west of Ellsworth is the flood plain more than a mile wide, and in many places it is less than a mile. From Ellsworth County eastward the valley gradually widens. At Marquette it is about 2 miles, at Lindsborg it is nearly 4 miles, at Bridgeport it is approximately 6 miles, and in the vicinity of Mentor and Salina it is 8 to 9 miles wide. From Salina to Solomon the valley is 3 to 4 miles wide, and the bluffs are relatively unimportant to below Abilene, from which point they begin to appear on either side of the stream and are prominent down to Junction.

The absence of pronounced bluff lines from Salina to below Abilene is explained by the character of the material in which the channel is cut. In this region the last remnants of the Permian rocks are exposed at the surface at the eastern part of the lowermost portions of the Dakota sandstone, a formation which is relatively soft and comparatively uniform throughout, so that it offers conditions favorable for rapid erosion and the gradual wearing away of bluff lines until they are unimportant. Below Salina the river meanders show angular curves and typical oxbow forms. As these curves are confined to the flood plain it is probable that they have been produced since the river reached base level in this part of the course. The valley of the Smoky Hill is not extensively filled with fluviatile débris, as is the valley of the Arkansas River.[1]

In most places over its flood plain the Cretaceous floor may be reached by digging a few feet, rarely more than 20, and in many places Cretaceous formations are exposed in the river channel. These conditions show that the river has scarcely reached base level and probably as far east as Salina is still deepening its channel. As a result nowhere along the course of the river through the area of Tertiary deposits is much underground water found in the valley, at least it is not found in sufficient quantities to be of much importance in irrigation. It is true that in places where the detritus has reached a thickness of 6 or more feet, considerable water can be obtained by digging, but, compared with the water of other areas, this is of little importance. Beyond the bluffs, however, and out on the broad plains of the great Tertiary areas water in great abundance is found. The valley, therefore, presents the anomalous condition of wells along the stream being barren while wells in the high uplands, a mile or more away, and from 200 to 300 feet above the river, are very productive.[2]

Measurements of the quantity of water carried by Smoky Hill River have been made by the United States Geological Survey at a gaging station located at Ellsworth, Kans. From the records at this station the mean monthly discharge of the river from April, 1895, to December, 1904, has been computed and the results are shown in Table 106.

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[1] Rept. Board of Irrigation Survey and Experiment for 1895 and 1896 to the Legislature of Kansas, p. 87

[2] Kansas Univ. Geol. Survey, vol. 2, pp. 35–39.

Table 106.—*Monthly discharge of Smoky Hill River near Ellsworth for period April, 1895, to December, 1904.*

[Drainage area, 7,980 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 172 | 14 | 45.6 |
| February | 213 | 17 | 57.2 |
| March | 1,410 | 14 | 36.5 |
| April | 1,834 | 10 | 93.5 |
| May | 11,392 | 13 | 321 |
| June | 4,856 | 10 | 410 |
| July | 7,947 | 5 | 448 |
| August | 862 | 5 | 256 |
| September | 7,840 | 12 | 170 |
| October | 1,390 | 14 | 477 |
| November | 187 | 8 | 423 |
| December | 268 | 12 | 347 |
| The period | 11,392 | 5 | 257.0 |

The United States Geological Survey maintained a sampling station on Smoky Hill River at Lindsborg from November 27, 1906, to November 29, 1907. Samples were collected by P. E. Gibson. A record of the analyses of the composite samples is presented in Table 107.

### QUALITY OF WATERS.

The water of Smoky Hill River is high in chlorides and very high in sulphates. In fact, though in 19 of the analyses of composite samples (Table 107) the bicarbonates predominate numerically over the sulphates, if these constituents be considered in terms of their chemical equivalents it appears that in 28 of the analyses the sulphates are in excess of the bicarbonates, and therefore the water of Smoky Hill River at Lindsborg must be regarded as usually belonging to the sulphate class. The periods when bicarbonates predominated over sulphates were from January 17 to February 7, and from April 8 to May 1.

From this it seems to be true that in the spring of the year and at other times when the flow of Smoky Hill River is largely made up of surface waters, the bicarbonates predominate; at other times, when the flow of the stream is largely due to the influx of ground waters, sulphates are in excess.

The permanent hardness of the water is very great, but the temporary hardness is not so pronounced (see assays 1–7, Table 102, analyses 1–6, Table 103, and Table 107).

Although the waters of the main stream carry a heavy burden of sulphates the water of its upper tributaries, notably Castle Hill, Ladder, and Big creeks bear much less. Now tests of underground water from the Tertiary deposits indicate that it is relatively free from sulphates except where those deposits are in immediate contact with the "Red Beds" and have become sulphated and in places salty by the upper movement of waters through the "Red Beds," which contain both gypsum and salt.[1] It might be expected, therefore, that in the western part of the State, where the flow of the river is largely kept up by water from the Tertiary deposits, sulphates would be low. The high sulphates in the Smoky Hill have been attributed by some investigators to evaporation, resulting in the concentration of the mineral constituents of the water, but if this were true the sulphates would be as high in the three creeks mentioned as in the main stream. At the sampling points neither Ladder Creek nor Castle Hill Creek had cut down to the Cretaceous floor, and Big Creek had not flowed far in the Cretaceous deposits. It is entirely probable, therefore, that the river extracts sulphates from the Cretaceous shales that form its bed and that the three creeks pick up less sulphates either because they have not yet cut down to the Cretaceous rocks or have eroded them but little. From the eastern boundary of Russell County to Kanopolis the high sulphates in the river may possibly in part be accounted for by the fact that the river is flowing through Dakota sandstone, certain beds of which contain sulphates in abundance. A marked increase in the chlorides in the water of Smoky Hill River below Russell Springs is shown by assay 7, Table 102, and the high chlorides in the water of the river between Ellsworth and Salina is confirmed by analyses of the composite samples of the river at Lindsborg (Table 107), as well as by analysis 6, Table 103. The increase in chlorides results chiefly from the operations of the salt works at Ellsworth and Kanopolis, where great salt deposits in the Permian are worked.

That the Smoky Hill is turbid a good deal of the time is shown by Table 108. About 34 per cent of the readings gave a turbidity value of less than 50, and nearly 40 per cent were 100 or greater. Two periods of long-continued marked turbidity were noted, one extending from March 18 to April 8, 1907, and the other from May 6 to 27, 1907. A brief period of very high turbidity extended from August 17 to 20, 1907. The highest turbidity that was reached while the river was under observation, 8,460, being recorded on August 17. The jump of the turbidity figure from 110 on August 16 to 8,460 on August 17 shows the rapidity with which the river sometimes changes; so does the rise from 24 on July 15 to 2,000 on July 16. The lowest turbidity, 7, was recorded on July 6, 1907.

The coefficient of fineness (column 5, Table 107) is obtained by dividing the suspended matter, expressed as parts per million, by the turbidity. The finer the material of the suspended matter the smaller the coefficient of fineness. It may be useful to remember that when the coefficient is less than 0.65 most of the suspended matter will pass through a slow sand filter. The high coefficient of fineness of Smoky Hill River indicates that the suspended matter is rather coarse; the sharp drop in turbidity after it has risen to a high figure points to the same fact.

[1] Kansas Univ. Geol. Survey, vol. 5, pp. 74-75.

TABLE 107.—*Analyses of water from Smoky Hill River, at Lindsborg, Kans.*

[Drainage area, 8,480 square miles. Quantities in analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Nov. 27 | Dec. 6 | 110 | 63 | 0.57 | 27 | a 0.9 | 112 | 21 | 171 | 0.0 | 258 | 227 | 0.5 | 203 | 893 |
| Dec. 7 | Dec. 16 | 63 | 44 | .70 | ........ | .8 | 123 | 24 | 150 | .0 | 203 | 254 | .4 | 230 | 981 |
| Dec. 17 | Dec. 26 | 55 | 45 | .82 | 49 | .40 | 116 | 26 | 172 | .0 | 305 | 250 | .8 | 214 | 954 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 26 | Jan. 6 | 31 | 30 | .97 | 27 | .8 | 111 | 13 | 210 | .0 | 277 | 220 | 1.8 | 240 | 939 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 7 | Jan. 17 | 53 | 53 | 1.00 | 24 | 1.0 | 120 | 14 | 161 | .0 | 295 | 227 | 3.5 | 192 | 899 |
| Jan. 18 | Jan. 28 | 385 | 283 | .74 | | | | | | | | | | | |
| Jan. 29 | Feb. 7 | 55 | 53 | .96 | 24 | 1.7 | 130 | 19 | 158 | .0 | 346 | 205 | 1.1 | 190 | 877 |
| Feb. 9 | Feb. 19 | 117 | 112 | .96 | 69 | .08 | 70 | 21 | 148 | .0 | 284 | 176 | .2 | 154 | 686 |
| Feb. 21 | Mar. 3 | 59 | 57 | .97 | 62 | .06 | 107 | 22 | 163 | .0 | 277 | 245 | 1.1 | 169 | 874 |
| Mar. 4 | Mar. 14 | 95 | 103 | 1.08 | 41 | .30 | 108 | 20 | 161 | .0 | 255 | 208 | .6 | 174 | 843 |
| Mar. 15 | Mar. 26 | 149 | 141 | .95 | 18 | .50 | 123 | 26 | 153 | .0 | 252 | 246 | 1.0 | 179 | 866 |
| Mar. 27 | Apr. 7 | 199 | 179 | .90 | 18 | .80 | 128 | 27 | 196 | .0 | 290 | 252 | .5 | 235 | 1,007 |
| Apr. 8 | Apr. 18 | 93 | 84 | .90 | 23 | .80 | 136 | 20 | 139 | .0 | 382 | 197 | .9 | 164 | 844 |
| Apr. 19 | May 1 | 115 | 90 | .78 | 17 | .80 | 117 | 23 | 176 | .0 | 310 | 219 | 1.5 | 216 | 901 |
| May 5 | May 15 | 214 | 204 | .95 | 16 | 1.2 | 112 | 27 | 199 | .0 | 290 | 239 | 1.5 | 251 | 960 |
| May 16 | May 26 | 405 | 297 | .73 | 19 | 1.0 | 120 | 19 | 202 | .0 | 285 | 257 | 2.0 | 246 | 997 |
| May 28 | June 9 | 29 | 32 | 1.10 | 11 | .8 | 122 | 34 | 199 | .0 | 300 | 243 | 2.2 | 251 | 1,004 |
| June 10 | June 21 | 35 | 30 | .86 | 22 | 1.0 | 100 | 23 | 195 | .0 | 255 | 217 | 2.8 | 242 | 917 |
| June 22 | July 2 | 62 | 52 | .84 | 26 | .8 | 133 | 29 | 163 | .0 | 215 | 286 | 3.2 | 191 | 929 |
| July 5 | July 16 | 243 | 141 | .58 | 39 | 2.5 | 158 | 28 | 106 | .0 | 172 | 401 | 5.0 | 103 | 941 |
| July 18 | July 29 | 1,210 | 914 | .76 | 29 | 4.0 | 68 | 9.5 | 38 | .0 | 165 | 77 | 3.0 | 54 | 357 |
| July 30 | Aug. 10 | 910 | 1,104 | 1.21 | 24 | 1.3 | 90 | 25 | 144 | .0 | 143 | 215 | 1.7 | 160 | 751 |
| Aug. 11 | Aug. 20 | 2,030 | 1,076 | .53 | 30 | .9 | 125 | 20 | 96 | .0 | 195 | 257 | 4.5 | 96 | 715 |
| Aug. 21 | Sept. 1 | 90 | 70 | .78 | 21 | .6 | 120 | 20 | 126 | .0 | 198 | 243 | 2.7 | 118 | 720 |
| Sept. 2 | Sept. 14 | 57 | 45 | .79 | 26 | .08 | 122 | 30 | 150 | b 6.0 | 195 | 284 | 2.0 | 175 | 886 |
| Sept. 22 | Oct. 8 | 143 | 122 | .85 | 24 | .50 | 101 | 15 | 168 | .0 | 215 | 256 | 2.3 | 204 | 896 |
| Oct. 10 | Oct. 27 | 78 | 61 | .78 | 20 | .12 | 124 | 22 | 195 | .0 | 235 | 235 | .9 | 230 | 927 |
| Oct. 28 | Nov. 16 | 51 | 50 | .98 | 27 | .16 | 114 | 26 | 200 | .0 | 295 | 242 | .9 | 256 | 982 |
| Nov. 17 | Nov. 29 | 29 | 21 | .72 | 24 | .12 | 93 | 24 | 178 | .0 | 275 | 255 | .8 | 227 | 738 |
| Mean........ | | 247 | 192 | .85 | 28 | .86 | 114 | 22 | 161 | .0 | 256 | 237 | 1.8 | 191 | 867 |
| Per cent of anhydrous residue..... | | .......... | .......... | .......... | 3.2 | .1 | 12.9 | 2.5 | 18.2 | 14.3 | .......... | 27.0 | .2 | 21.6 | .......... |

a Aluminum=0.8.

b Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from November 27, 1906, to February 7, 1907, and from March 15 to November 16, 1907, by F. W. Bushong; from February 9 to March 14, 1907, and from November 17 to 29, 1907, by Archie J. Weith.

TABLE 108.—*Turbidity of daily samples from Smoky Hill River at Lindsborg, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | 1906. | | 1907. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
| 1 | ...... | 110 | 23 | 34 | 120 | 150 | 36 | ...... | 50 | 2,640 | 65 | ...... | ...... |
| 2 | ...... | 120 | 36 | 70 | 95 | ...... | ...... | 32 | 53 | 2,160 | 80 | ...... | ...... |
| 3 | ...... | 75 | 26 | 65 | 42 | ...... | ...... | 32 | ...... | 2,650 | ...... | ...... | 120 |
| 4 | ...... | 100 | 8 | 65 | 43 | 242 | ...... | ...... | ...... | 666 | 75 | ...... | 50 |
| 5 | ...... | 180 | ...... | 60 | 100 | 220 | 125 | 32 | 45 | 60 | 60 | ...... | 70 |
| 6 | ...... | 105 | 18 | 60 | 90 | 220 | 125 | 30 | 7 | 80 | ...... | ...... | 80 |
| 7 | ...... | 100 | 32 | 105 | 30 | 170 | 60 | 26 | 8 | 95 | ...... | 680 | 45 |
| 8 | ...... | 85 | ...... | ...... | 30 | 160 | 120 | ...... | 30 | ...... | 45 | 270 | 80 |
| 9 | ...... | 65 | 16 | 75 | 105 | 38 | 170 | 27 | 45 | 75 | 40 | ...... | 32 |
| 10 | ...... | 30 | 13 | 65 | 105 | 24 | ...... | 27 | ...... | 65 | 85 | 185 | 18 |
| 11 | ...... | 50 | 27 | 120 | 200 | 36 | 385 | ...... | ...... | 50 | 70 | 180 | ...... |
| 12 | ...... | 110 | 27 | 130 | 90 | 23 | 412 | ...... | 60 | 60 | 32 | ...... | ...... |
| 13 | ...... | 115 | 25 | 135 | ...... | 180 | 210 | 55 | 95 | 15 | 18 | ...... | ...... |
| 14 | ...... | 30 | 30 | 135 | 160 | 145 | 300 | 38 | 120 | 120 | 60 | 50 | ...... |
| 15 | ...... | 32 | 248 | 180 | 70 | 23 | 235 | 42 | 24 | 120 | ...... | 50 | 80 |
| 16 | ...... | 16 | 65 | 160 | 40 | ...... | 220 | 40 | 2,000 | 110 | ...... | 70 | 45 |
| 17 | ...... | 45 | 43 | 110 | 60 | 170 | 215 | 24 | ...... | 8,460 | ...... | ...... | 18 |
| 18 | ...... | 36 | 18 | ...... | 100 | 130 | 485 | 43 | 4,000 | 4.530 | ...... | ...... | 32 |
| 19 | ...... | 16 | 15 | 65 | ...... | 75 | ...... | 33 | 700 | 3,372 | ...... | ...... | 45 |
| 20 | ...... | 20 | 730 | ...... | 105 | ...... | 460 | 32 | 300 | 3,480 | ...... | ...... | 24 |
| 21 | ...... | 15 | 1,600 | 42 | 150 | 180 | 532 | 18 | 40 | 100 | ...... | 70 | ...... |
| 22 | ...... | 68 | 700 | 50 | 160 | 95 | 485 | 55 | 1.866 | ...... | 120 | 65 | 18 |
| 23 | ...... | 18 | 425 | ...... | 300 | 120 | 418 | 27 | 3.900 | 155 | 125 | 30 | ...... |
| 24 | ...... | 95 | ...... | 32 | ...... | 155 | 320 | 27 | 370 | 85 | 50 | 80 | 24 |
| 25 | ...... | 20 | 140 | 36 | 295 | ...... | 412 | 33 | ...... | 90 | 45 | 90 | 45 |
| 26 | ...... | 212 | 135 | 42 | 210 | 150 | 500 | 30 | ...... | 130 | 80 | 60 | 40 |
| 27 | 77 | 31 | 55 | 42 | 305 | ...... | ...... | 22 | 160 | ...... | 110 | 80 | 45 |
| 28 | 65 | 34 | 27 | 65 | 180 | 210 | 20 | 130 | 150 | 100 | 50 | 70 | 18 |
| 29 | 135 | ...... | 28 | ...... | 135 | 50 | 30 | 125 | 613 | 95 | 80 | ...... | 15 |
| 30 | 135 | 110 | 27 | ...... | 220 | 80 | 30 | 125 | 613 | 70 | 80 | ...... | ...... |
| 31 | ...... | 22 | 34 | ...... | 145 | ...... | 34 | ...... | ...... | 18 | ...... | ...... | ...... |
| Mean | 103 | 69 | 163 | 81 | 132 | 127 | 254 | 44 | 663 | 1,059 | 68 | 135 | 45 |

NOTE.—Turbidities over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

In its course from Salina to Junction Smoky Hill River cuts across the central or Gypsum City gypsum area,[1] the most important part of which lies south of Smoky Hill River, north of the Chicago, Rock Island & Pacific Railway, and west of the Atchison, Topeka & Santa Fe Railway. The largest of the tributaries of the Smoky Hill that drain this central gypsum area are Gypsum, Holland, and Turkey creeks from the south and Abilene and Chapman creeks from the north.

On Gypsum Creek the gypsum rock is exposed at various places along the east bank between Gypsum City and Solomon. Analysis 8, Table 103, and assay 12, Table 102 (pp. 206, 204), are tests of the water of Gypsum Creek, and clearly indicate the influence of the gypsum on the water, for it is high in calcium and sulphates.

No test was made of the water of Holland Creek.

The water of Abilene Creek is shown by assay 22, Table 102, to be high in sulphates, probably derived from the gypsum-earth deposit at Manchester, which lies within the creek basin.

[1] Kansas Univ. Geol. Survey, vol. 5, pp. 35–37, and pp. 58 to 65.

The water of Turkey Creek is shown by assay 23, Table 102 (p. 204), and analysis 13, Table 103 (p. 206), to be the most heavily mineralized surface water tested in this investigation. The only other surface water of a comparable degree of mineralization is that of Whitewater River (assays 40 to 42, Table 145, and analyses 22 and 23, Table 146), which also drains an area of gypsum deposits. Within the catchment area of Turkey Creek there are gypsum-earth deposits near Rhodes, Banner City, and Dillon, and near Dillon gypsum rock also outcrops. The water of Chapman Creek (assay 24, Table 102, p. 204) carries a heavy load of sulphates, which is probably in part derived from the gypsum-earth deposit at Longford. Lyons Creek, the water of which enters the Smoky Hill a little above Junction, though much lower in sulphates (assay 26, Table 102) than are the waters of Gypsum, Holland, Abilene, Turkey, and Chapman creeks, carries an excessive amount of sulphates. These possibly may in part be traced to the gypsum-earth deposit east of Hope on the west branch of Lyons Creek.

Erasmus Haworth (by letter) says that in some places in Dickinson County the gypsum is exposed immediately at the surface, with hardly enough soil covering to hold water in contact with it an hour after the rain, and that the same is true in Barber County, a little farther west. So the high sulphate content of the streams that drain the areas of gypsum deposits in these counties is not surprising.

## SALINE RIVER.[1]

### DESCRIPTION.

The drainage basin of Saline River is wholly in Kansas and is 3,311 square miles in area. The Saline rises in the southwestern part of Thomas County and flows nearly due east into Smoky Hill River. The upper course of the Saline is dry during almost the entire year, for it has not sunk its channel deep enough into the Tertiary deposits to be fed by their groundwaters. Farther east, however, it cuts deeper and deeper into the Tertiary until north of Grainfield the presence of bogs and ponds shows that the valley has been eroded down to sheet water. Northeast of Buffalo Park Saline River has cut down to the Cretaceous floor on which the Tertiary rests, and in this it flows for the remainder of its course—a perennial stream, deriving its chief supply from springs in the Tertiary deposits and the Dakota sandstone.

The valley of Saline River in the western part of the State is extremely narrow, but eastward in Ellis County it widens gradually to a mile or more, and still farther down it is 2 to 4 miles in width. At the head of the river the bluff lines are inconspicuous, but not far below the source the stream channel is sunk to a depth of 20 to 40 feet, the depth continuing to increase gradually eastward until the

[1] Kansas Univ. Geol. Survey, vol. 2, pp. 39-40.

river reaches the Cretaceous formations in Ellis and Russell counties, where the bluffs are in many places 100 feet or more high. In the vicinity of Salina, some distance back from the river, hills of the Dakota sandstone rise nearly 200 feet above the level of the water in the river.

The name Saline is well merited by the river, for chemical analysis shows that it is one of the saltiest streams in the United States. The salt is acquired from salt springs, some of which occur in the very bed of the stream or in the beds of its tributaries, such as Salt Creek north of Russell. The salt of these springs and creeks is derived from the saliferous shales of the Dakota, which occur near the top of that formation. They rest on a thin bed of lignite and are 15 to 30 feet thick; overlying them is a bed of gypsiferous shales 10 to 20 feet thick, and on top of all is a layer of sandstone 8 to 12 inches thick. This sandstone, lithologically as well as paleontologically, marks the separation of the Benton from the Dakota.

The discharge of Saline River at Beverly and Salina is shown in the following tables:

TABLE 109.—*Mean monthly discharge of Saline River at Beverly, Kans., for the period April, 1895, to June, 1897.*

[Drainage area, 2,730 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 108 | 17 | 50.0 |
| February | 243 | 27 | 62.0 |
| March | 67 | 27 | 47.4 |
| April | 693 | 20 | 126 |
| May | 3,000 | 14 | 166 |
| June | *a* 16,000 | 21 | 1,020 |
| July | *a* 10,000 | 73 | 430 |
| August | 493 | 41 | 104 |
| September | 92 | 9 | 48.0 |
| October | *a* 6,130 | 6 | 144 |
| November | 188 | 9 | 54.0 |
| December | 98 | 13 | 47.6 |
| The period | *a* 16,000 | 6 | 192 |

*a* Maximum estimated.

TABLE 110.—*Mean monthly discharge of Saline River near Salina, Kans., for 1897 to 1903.*

[Drainage area, 3,311 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 240 | 40 | 83.0 |
| February | 260 | 34 | 83.5 |
| March | 1,340 | 24 | 163 |
| April | 3,580 | 24 | 222 |
| May | 7,580 | 18 | 524 |
| June | 7,900 | 37 | 878 |
| July | 3,370 | 22 | 288 |
| August | 3,410 | 7 | 323 |
| September | 3,920 | 6 | 227 |
| October | 3,920 | 16 | 221 |
| November | 424 | 15 | 112 |
| December | 690 | 28 | 102 |
| The period | 7,900 | 6 | 269 |

## QUALITY OF WATER.

The United States Geological Survey maintained a daily sampling station on Saline River at Sylvan Grove from November 27, 1906, to November 30, 1907. The collector was Edward Buehring.

A record of the analyses of composite samples of the waters collected at this sampling station is presented in Table 111. The analyses show a very heavily mineralized sodic saline water. The chlorides and sulphates are very high, in marked accordance with the fact that the river receives large contributions of water from the saliferous and gypsiferous shales of the Dakota. The chlorides and sulphates in all but six of the analyses fluctuate in the same direction; indeed, the ratio of chlorides to sulphates is fairly constant.

On the assumption that rise and fall of turbidity denote rise and fall in river stage, it appears from Table 111 that the total dissolved solids follow fluctuations in the stage of the river somewhat closely. This is natural, because rain, melting snows, and surface waters in general, are less highly mineralized than the spring waters that feed the Saline, and therefore dilute the river water when they reach the river in considerable volume. Analysis 7, Table 103, is a test of Saline River at its mouth.

The record of turbidity of the daily samples from Saline River, Table 112, shows that it is not a very turbid stream. During the six months from December, 1906, to May, 1907, the samples only once had a turbidity of greater than 100, and for more than half of this period the turbidity was less than 50. Through November, 1907, the turbidity was always less than 100 and for more than half of the time was less than 50. During the entire time the Saline was sampled over 43 per cent of the readings were less than 50, and only about 24 per cent of the time were they greater than 100. The longest period of high turbidity extended from June 26 to September 5, in which time the turbidity was less than 100 on only one day. The highest turbidity, 10,080, was recorded on May 26, and the lowest, 5, on February 5. The increase in turbidity was at times very great and sudden, as from 145 on July 15 to 4,080 on July 16, and from 160 on June 10 to 1,530 on June 11. The coefficient of fineness, Table 111, indicates that the suspended matter is somewhat coarser than that of Smoky Hill River. Assays 9 and 11, Table 102, are tests of tributaries that are affected by salt springs, and assays 8 and 10, Table 102, show how the river is influenced by one of these salty tributaries. Paradise Creek, in Russell County, is said to have salt springs that discharge into it.

TABLE 111.—*Analyses of water from Saline River, at Sylvan Grove, Kans.*

[Drainage area 2,300 square miles. Quantities in parts per million. Analyses made by F. W. Bushong in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Nov. 27 | Dec. 6 | 65 | 46 | 0.71 | 27 | [a]0.9 | 114 | 47 | 738 | 0.0 | 370 | 497 | 0.4 | 982 | 2,623 |
| Dec. 7 | Dec. 16 | 33 | 28 | .85 | .... | 1.2 | 147 | 56 | 852 | .0 | 382 | 540 | .4 | 1,108 | 2,910 |
| Dec. 17 | Dec. 26 | 41 | 25 | .61 | 55 | 1.0 | 152 | 58 | 865 | .0 | 407 | 566 | .7 | 1,170 | 3,086 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 27 | Jan. 5 | 45 | 66 | 1.46 | 28 | 1.0 | 137 | 46 | 681 | .0 | 327 | 480 | .4 | 980 | 2,688 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 6 | Jan. 15 | 27 | 44 | 1.63 | 23 | 1.2 | 148 | 56 | 807 | .0 | 334 | 541 | 1.4 | 1,086 | 2,832 |
| Jan. 16 | Jan. 25 | 27 | 31 | 1.15 | 44 | 1.2 | 151 | 52 | 777 | .0 | 427 | 521 | .9 | 1,004 | 2,784 |
| Jan. 26 | Feb. 4 | 28 | 31 | 1.10 | 49 | .6 | 148 | 51 | 714 | .0 | 320 | 554 | .4 | 954 | 2,648 |
| Feb. 5 | Feb. 15 | 49 | 56 | 1.14 | 20 | .14 | 144 | 52 | 776 | .0 | 406 | 530 | .2 | 1,041 | 2,716 |
| Feb. 16 | Feb. 25 | 46 | 45 | .98 | 93 | .30 | 145 | 41 | 726 | .0 | 367 | 462 | .4 | 934 | 2,566 |
| Feb. 26 | Mar. 7 | 37 | 30 | .81 | 86 | .62 | 159 | 55 | 866 | .0 | 374 | 520 | .4 | 1,131 | 3,031 |
| Mar. 8 | Mar. 17 | 32 | 30 | .94 | 23 | .25 | 115 | 54 | 774 | [b]3.1 | 311 | 475 | .2 | 960 | 2,503 |
| Mar. 18 | Mar. 27 | 49 | 56 | 1.14 | 18 | .8 | 145 | 59 | 822 | .0 | 336 | 549 | .6 | 1,118 | 2,884 |
| Mar. 28 | Apr. 7 | 70 | 54 | .77 | 14 | .8 | 144 | 62 | 934 | .0 | 330 | 427 | .4 | 1,269 | 3,200 |
| Apr. 8 | Apr. 17 | 51 | 47 | .92 | 13 | 3.2 | 151 | 63 | 971 | .0 | 337 | 607 | .4 | 1,339 | 3,357 |
| Apr. 18 | Apr. 27 | 44 | 41 | .93 | 10 | 1.6 | 142 | 68 | 1,021 | .0 | 345 | 551 | .7 | 1,380 | 3,408 |
| Apr. 28 | May 9 | 41 | 38 | .93 | 12 | 1.5 | 134 | 62 | 949 | .0 | 340 | 582 | .9 | 1,280 | 3,176 |
| May 10 | May 20 | 50 | 46 | .92 | 14 | .50 | 138 | 60 | 1,005 | .0 | 320 | 621 | 1.0 | 1,348 | 3,370 |
| May 21 | May 31 | 43 | 42 | .98 | 15 | 1.2 | 136 | 67 | 1,150 | .0 | 322 | 670 | .6 | 1,580 | 3,835 |
| June 3 | June 12 | 218 | 147 | .67 | 15 | 3.0 | 120 | 53 | 862 | .0 | 277 | 498 | .9 | 1,148 | 2,880 |
| June 13 | June 22 | 75 | 67 | .89 | 17 | 1.4 | 116 | 44 | 689 | .0 | 282 | 447 | 1.1 | 928 | 2,423 |
| June 23 | July 5 | 1,130 | 1,330 | 1.18 | 35 | 4.0 | 97 | 32 | 295 | .0 | 208 | 273 | 4.5 | 368 | 1,210 |
| July 6 | July 15 | 590 | 511 | .87 | 27 | 1.2 | 110 | 24 | 392 | .0 | 252 | 302 | 1.7 | 504 | 1,485 |
| July 16 | July 25 | 860 | 754 | .88 | 28 | 1.2 | 114 | 26 | 238 | .0 | 238 | 245 | 1.5 | 276 | 1,043 |
| July 26 | Aug. 4 | 240 | 187 | .78 | 27 | 1.8 | 120 | 42 | 444 | [b]9.0 | 225 | 350 | .7 | 592 | 1,712 |
| Aug. 5 | Aug. 14 | 158 | 150 | .95 | 27 | 1.8 | 124 | 45 | 591 | .0 | 263 | 401 | 1.0 | 796 | 2,106 |
| Aug. 16 | Aug. 26 | 916 | 460 | .50 | 32 | 3.4 | 84 | 22 | 182 | .0 | 222 | 153 | 2.7 | 224 | 790 |
| Aug. 27 | Sept. 5 | 140 | 141 | 1.00 | 31 | .12 | 106 | 37 | 425 | [b]6.0 | 252 | 296 | 1.3 | 564 | 1,571 |
| Sept. 6 | Sept. 17 | 72 | 71 | .99 | 27 | .05 | 125 | 60 | 905 | .0 | 305 | 457 | 1.1 | 1,023 | 2,587 |
| Sept. 18 | Sept. 28 | 78 | 66 | .85 | 15 | .12 | 142 | 79 | 1,022 | .0 | 305 | 578 | 3.8 | 1,448 | 3,488 |
| Sept. 29 | Oct. 10 | 668 | 646 | .97 | 19 | .12 | 124 | 43 | 555 | [b]3.0 | 290 | 366 | 3.0 | 741 | 1,998 |
| Oct. 12 | Oct. 22 | 46 | 55 | 1.20 | 17 | .10 | 148 | 74 | 991 | .0 | 355 | 562 | .6 | 1,340 | 3,366 |
| Oct. 23 | Nov. 2 | 55 | 43 | .78 | 18 | .18 | 167 | 61 | 973 | .0 | 355 | 554 | .7 | 1,300 | 3,382 |
| Nov. 3 | Nov. 13 | 43 | 25 | .58 | 27 | .40 | 149 | 40 | 932 | .0 | 380 | 554 | .3 | 1,268 | 3,191 |
| Nov. 14 | Nov. 29 | 41 | 23 | .56 | 23 | .10 | 109 | 64 | 914 | .0 | 390 | 544 | .6 | 1,216 | 3,010 |
| Mean | | 180 | 160 | .93 | 28 | 1.1 | 132 | 52 | 760 | .0 | 323 | 479 | 1.0 | 1,012 | 2,908 |
| Per cent of anhydrous residue | | ...... | ...... | ...... | 1.1 | .1 | 5.0 | 2.0 | 29.0 | 6.0 | ...... | 18.2 | .1 | 38.5 | ...... |

[a] Al, 2.

[b] Abnormal; computed as $HCO_3$ in the average.

TABLE 112.—*Turbidity of daily samples from Saline River at Sylvan Grove, Kans.*

[Readings made in the chemical laboratories of the University of Kansas. E. H. S. Bailey, director.]

| Day. | 1906. | | 1907. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
| 1 | ...... | 33 | 34 | 22 | 28 | 100 | 60 | ...... | ...... | 180 | 145 | 4,000 | 60 |
| 2 | ...... | 56 | 68 | 22 | 34 | 70 | ...... | ...... | 632 | 180 | ...... | 1,800 | 32 |
| 3 | ...... | 50 | 42 | 27 | 36 | 85 | 67 | 60 | 418 | 120 | 125 | 425 | 50 |
| 4 | ...... | 95 | 26 | 18 | 38 | 95 | 20 | 36 | 350 | 70 | 145 | 340 | 50 |
| 5 | ...... | 140 | 36 | 5 | 32 | 62 | 35 | 55 | 200 | 160 | 110 | 225 | 40 |
| 6 | ...... | 32 | 24 | 15 | 30 | 60 | ...... | 45 | 200 | 160 | 100 | 135 | 36 |
| 7 | ...... | 26 | 18 | ...... | 60 | 65 | 34 | 80 | 110 | 125 | ...... | 130 | ...... |
| 8 | ...... | 32 | 35 | 5 | 43 | 40 | 48 | 55 | 190 | 125 | 80 | ...... | 24 |
| 9 | ...... | 25 | 24 | 18 | 16 | 46 | 24 | 37 | 130 | 135 | 70 | 50 | 24 |
| 10 | ...... | 24 | 25 | 32 | 34 | 65 | 40 | 160 | 190 | 140 | 55 | 95 | 15 |
| 11 | ...... | 18 | 18 | 15 | 36 | 47 | 55 | 1,530 | 140 | 130 | 50 | ...... | 70 |
| 12 | ...... | 65 | 20 | 30 | 50 | 75 | 33 | 120 | 145 | 140 | 80 | 60 | 50 |
| 13 | ...... | 75 | 36 | 210 | 34 | 55 | 65 | 75 | 145 | 115 | 70 | ...... | 70 |
| 14 | ...... | 24 | 32 | 90 | 13 | 24 | 60 | 90 | 4,080 | 350 | 85 | 36 | 80 |
| 15 | ...... | 20 | 35 | 70 | 20 | 65 | 34 | 80 | 580 | ...... | 75 | 70 | 24 |
| 16 | ...... | 20 | 30 | 45 | 36 | 65 | 55 | 65 | 500 | 220 | 55 | 70 | 32 |
| 17 | ...... | 28 | 20 | 95 | 40 | 26 | 58 | 120 | 3,678 | 190 | 65 | 45 | 45 |
| 18 | ...... | 20 | 34 | 95 | 45 | 53 | 65 | 65 | 1,666 | 1,000 | 110 | 40 | 45 |
| 19 | ...... | 20 | 16 | 34 | 50 | 16 | ...... | 65 | 800 | 1,800 | 90 | 45 | 45 |
| 20 | ...... | 15 | 10 | 38 | 50 | 50 | 38 | 70 | 765 | 966 | 70 | 65 | 40 |
| 21 | ...... | 25 | 15 | 42 | 32 | 40 | 35 | 58 | 340 | 800 | 60 | 40 | ...... |
| 22 | ...... | 28 | 60 | 32 | 43 | 58 | 45 | 60 | 304 | 650 | 24 | 50 | 30 |
| 23 | ...... | 50 | 27 | 22 | 36 | 42 | 65 | 70 | 265 | 440 | 65 | 70 | 24 |
| 24 | ...... | 45 | 24 | 40 | 50 | 55 | 60 | 58 | 160 | 370 | 65 | 60 | 50 |
| 25 | ...... | 90 | 30 | 12 | 65 | 55 | ...... | ...... | 140 | 260 | 80 | 55 | 40 |
| 26 | ...... | 85 | 36 | 42 | 55 | 34 | 65 | 10,080 | 340 | 322 | 80 | 60 | 32 |
| 27 | 45 | 75 | 28 | 50 | 65 | 36 | 32 | 4,590 | 460 | 300 | 120 | 32 | 70 |
| 28 | 77 | 30 | 28 | 20 | 65 | 65 | 43 | 1,800 | 240 | 240 | 90 | 32 | 30 |
| 29 | 48 | 60 | 27 | ...... | ...... | 34 | 22 | 933 | 406 | 225 | 70 | 36 | 32 |
| 30 | 73 | 50 | 36 | ...... | 65 | 20 | 28 | ...... | 210 | ...... | 80 | 45 | ...... |
| 31 | ...... | 47 | 34 | ...... | 28 | ...... | 34 | ...... | 210 | 150 | ...... | 70 | ...... |
| Mean | 61 | 45 | 30 | 42 | 41 | 53 | 45 | 787 | 600 | 347 | 83 | 292 | 42 |

NOTE.—Turbidities over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

## SOLOMON RIVER.[1]

### DESCRIPTION.

Solomon River is formed by the junction of two forks. The North Fork rises in the southwestern part of Thomas County and flows northeastward to Kirwin, where it turns and flows southeastward to its union with the South Fork, south of Cawker. The South Fork heads in the southeastern part of Sherman County, and takes a slight northeasterly course to the point of junction. The headwaters of North and South Forks are not 10 miles apart but their courses are so divergent that the upland between the two in Norton, Graham, Phillips, and Rooks counties is nearly 20 miles wide and in the vicinity of Stockton and Marvin is 300 feet above the two valleys. Both streams rise in a region of Tertiary deposits and complete their course in the Cretaceous. The upper courses of these forks are dry during the greater part of the year because they lie in a region of deficient rainfall and because they have not cut deep enough into the Tertiary deposits to tap the underground water of

[1] Kansas Univ. Geol. Survey, Vol. 2, pp. 40–41.

those deposits. As they pass eastward their channels gradually become deeper and their valleys broader. At Stockton the valley of South Fork is about a mile wide and at Marvin, directly north, the valley of North Fork has the same width.

From the junction of its forks at Cawker to its mouth at Solomon the Solomon flows in a valley which averages 2 miles in width, but in places measures 3 miles. The river flows in Cretaceous deposits to a point a little south of Minneapolis, where it enters the Permian, in which it continues till it joins Smoky Hill River.

It should be noted that two of the affluents of Solomon River—Salt Creek and Plum Creek—carry salt water. Plum Creek, which is the less important of the two, carries the drainage of a small salt marsh into the river at a point below Beloit. Salt Creek is a rather large stream, though in its upper reaches it is often dry. In Lincoln County it receives the drainage of two salt marshes, one of which is on Rattlesnake Creek and the other at the junction of Prosser and Battle creeks. All of these salt marshes are fed by water which is mineralized by the saliferous shales of the Dakota sandstone.

The drainage area of Solomon River is 6,882 square miles. The discharge of the river as measured at Beloit and Niles is shown in the following tables:

TABLE 113.—*Mean monthly discharge of Solomon River near Beloit, Kans., for period July 1, 1895, to June 30, 1897, inclusive.*

[Drainage area, 5,540 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 1,160 | 5 | 109 |
| February | 3,055 | 19 | 148 |
| March | 1,160 | 8 | 161 |
| April | 18,500 | 8 | 1,160 |
| May | 4,700 | 72 | 290 |
| June | 8,740 | 104 | 1,110 |
| July | 21,800 | 108 | 1,720 |
| August | 24,000 | 92 | 992 |
| September | 960 | 14 | 143 |
| October | 6,760 | 7 | 165 |
| November | 1,120 | 7 | 245 |
| December | 930 | 7 | 103 |
| The period | 24,000 | 5 | 529 |

TABLE 114.—*Mean monthly discharge of Solomon River at Niles, Kans., for period beginning May 1, 1897, ending November 30, 1903.*

[Drainage area, 6,820 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 410 | 46 | 160 |
| February | 830 | 54 | 169 |
| March | 5,002 | 38 | 437 |
| April | 4,627 | 54 | 320 |
| May | 9,946 | 38 | 944 |
| June | 10,602 | 46 | 1,380 |
| July | 7,040 | 7 | 841 |
| August | 7,091 | 7 | 750 |
| September | 7,040 | 42 | 453 |
| October | 7,780 | 38 | 451 |
| November | 855 | 38 | 213 |
| December | 490 | 54 | 150 |
| The period | 10,602 | 7 | 522 |

QUALITY OF WATER.

Although the Solomon and the Saline lie side by side, in basins having essentially the same rainfall, topography, and surface geology, the waters of the Solomon are not highly charged with salt. The explanation seems to be that the waters from the saliferous shales of the Dakota find ready access to the bed of Saline River, whereas to the bed of Solomon River they have made their way in but a few places.

The United States Geological Survey maintained a daily sampling station at Beloit from December 1, 1906 to November, 1907, samples being collected by A. T. Rodgers.

The analyses of composite samples, Table 115, show that at this place Solomon River carries much better water than either the Smoky Hill or the Saline. This is because at Beloit the Solomon has received too little ground water from the Dakota sandstone to become heavily mineralized. Still, the temporary hardness of the river is high and the permanent hardness very great, though the sulphates are considerably lower than in the Smoky Hill and Saline. The chlorides in the Solomon at Beloit, though high, are a great deal less than in the two other rivers at the places where the daily sampling stations were maintained, and the fairly constant ratio between sulphates and chlorides that exists in the Saline does not appear in the analyses of the Solomon.

The chlorides in the river at Beloit are in part derived from salt springs on Carr and Hardscrabble creeks and from the seepage of the Waconda Springs, all of which are in Mitchell County. These salt springs originate in the saliferous and gypsiferous shales of the Dakota sandstone, and other springs having the same origin probably occur in the river valley above Beloit.

The total dissolved solids rise and fall with the gage heights less regularly than they do in Saline River, because the water of the Solomon is less heavily mineralized, being more like the surface water that reaches it in time of moderate rainfall. Thus only the heavy rains effect a marked dilution of the matter held in solution by the water of the river.

The Solomon is one of the clearest of the Kansas streams, its turbidity (Table 116) being generally low. During December, January, February, and November, 1906, the turbidity did not measure above 50, and from December to June 27 it was never above 100, nor did it rise above 100 in September. Over 66 per cent of all the samples had a turbidity of less than 50 and only about 13 per cent had a turbidity of 100 or more. The longest period of marked turbidity extended from June 27 to August 6, inclusive. The only other period of continued high turbidity extended from September 30 to October 13, inclusive. The highest observed turbidity was 40,458 on June 27, and the lowest was 2 on January 16. Turbidity of less than 10 was recorded eighteen times. There are great jumps in the turbidity, as from 35 on June 26 to 40,458 on June 27, and from 140 on July 24, to 3,900 on July 25. The coefficient of fineness (Table 115) is less for Solomon River than for either the Smoky Hill or Saline. Still the suspended matter is fairly coarse and settles out rapidly.

Assay 19, Table 102, shows the water of Pipe Creek at Minneapolis to be soft. Analysis 10, Table 103, is not greatly unlike the analyses of the composite samples at Beloit of the dates October 3–16 and October 18–28. Assay 20, Table 102, is a test of Salt Creek west of Minneapolis, and shows, as might be expected from the name, high chlorides. The creek receives the salt from salt springs in Mitchell County, the salt marsh at the junction of Battle and Prosser creeks, and probably from other salt springs. The influence of the water of this creek on Solomon River is shown by assay 21, Table 102, and analysis 11, Table 103, which indicate that Solomon River is much more salty below the mouth of Salt Creek than at Beloit and Minneapolis above, being in fact so heavily mineralized at Solomon that it is comparable with the water of Smoky Hill River at Lindsborg. This change in the quality of the water of the Solomon is due to the fact that below Minneapolis the river has a considerable drainage area, in which the general character of the water is determined by water originating in the gypsiferous and saliferous shales of the Dakota and by a considerable drainage that enters the river from an area within which the occurrence of gypsum may be expected.

TABLE 115.—*Analyses of water from Solomon River at Beloit, Kans.*

[Drainage area, 5,540 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. | Mean gage height (feet). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | | |
| Dec. 1 | Dec. 13 | 25 | 14 | 0.56 | 35 | 1.0 | 112 | 16 | 107 | 0.0 | 337 | 118 | 0.4 | 56 | 534 | .... |
| Dec. 14 | Dec. 24 | 18 | 14 | .78 | 19 | .9 | 109 | 20 | 95 | .0 | 366 | 118 | 2.7 | 80 | 615 | .... |
| | 1907. | | | | | | | | | | | | | | | |
| Dec. 25 | Jan. 3 | 13 | 10 | .77 | 32 | 1.0 | 107 | 15 | 82 | a8.4 | 325 | 116 | 4.6 | 72 | 585 | .... |
| 1907. | | | | | | | | | | | | | | | | |
| Jan. 4 | Jan. 13 | 20 | 14 | .70 | 37 | 1.2 | 116 | 20 | 70 | .0 | 319 | 118 | 4.8 | 58 | 525 | 0.8 |
| Jan. 15 | Jan. 24 | 9 | 15 | 1.66 | 48 | 1.6 | 109 | 15 | 98 | ...... | ...... | 134 | 4.4 | ...... | 655 | .6 |
| Jan. 25 | Feb. 3 | 7 | 7.4 | 1.06 | 51 | .8 | 91 | 12 | 94 | a2.4 | 208 | 148 | 3.0 | 71 | 602 | .6 |
| Feb. 4 | Feb. 24 | 19 | 9 | .47 | 39 | .20 | 94 | 13 | 74 | .0 | 303 | 71 | 3.9 | 57 | 544 | .9 |
| Feb. 25 | Mar. 6 | 17 | 8.4 | .49 | 95 | .20 | 94 | 18 | 95 | .0 | 317 | 112 | 4.8 | 62 | 625 | .7 |
| Mar. 7 | Mar. 16 | 22 | 19 | .86 | 28 | .18 | 95 | 15 | 72 | .0 | 306 | 110 | 3.0 | 50 | 509 | 1.6 |
| Mar. 17 | Mar. 26 | 50 | 12 | .24 | 31 | 4.0 | 89 | 8.2 | 76 | .0 | 300 | 103 | 1.0 | 54 | 514 | .9 |
| Mar. 27 | Apr. 6 | 47 | 29 | .62 | 29 | .6 | 91 | 10 | 85 | a5.3 | 302 | 110 | .4 | 66 | 544 | 1.1 |
| Apr. 7 | Apr. 17 | 52 | 42 | .81 | 28 | 1.6 | 95 | 15 | 83 | a7.0 | 330 | 113 | .6 | 46 | 552 | .6 |
| Apr. 27 | May 6 | 32 | 19 | .59 | 24 | 2.4 | 98 | 19 | 83 | .0 | 327 | 110 | 1.0 | 64 | 526 | 1.2 |
| May 7 | May 16 | 41 | 26 | .63 | 28 | .9 | 98 | 9.3 | 76 | .0 | 305 | 108 | 1.5 | 63 | 527 | 1.5 |
| May 17 | May 27 | 36 | 24 | .67 | 32 | 1.1 | 94 | 3 | 106 | a14.0 | 295 | 118 | 1.5 | 98 | 606 | 1.2 |
| May 28 | June 6 | 46 | 26 | .56 | 30 | .8 | 99 | 19 | 104 | .0 | 333 | 117 | 1.8 | 88 | 617 | 1.5 |
| June 7 | June 16 | 67 | 55 | .82 | 31 | 2.0 | 82 | 15 | 72 | .0 | 267 | 102 | 2.7 | 49 | 476 | 1.4 |
| June 17 | June 26 | 50 | 43 | .86 | 39 | 2.0 | 86 | 20 | 83 | .0 | 295 | 101 | 3.5 | 60 | 508 | 1.5 |
| June 27 | July 8 | 7,767 | 4,526 | .58 | 34 | 5.0 | 73 | 17 | 53 | .0 | 218 | 92 | 12.0 | 36 | 428 | 4.0 |
| July 9 | July 18 | 156 | 102 | .65 | 51 | 3.0 | 91 | 20 | 61 | .0 | 272 | 99 | 2.8 | 32 | 460 | 1.4 |
| July 19 | July 28 | 750 | 579 | .77 | 36 | 6.0 | 66 | 12 | 42 | .0 | 165 | 76 | 5.5 | 22 | 330 | 2.3 |
| July 29 | Aug. 7 | 195 | 146 | .75 | 28 | 4.0 | 80 | 25 | 67 | .0 | 254 | 83 | 7.5 | 50 | 429 | .... |
| Aug. 8 | Aug. 17 | 32 | 26 | .81 | 39 | .50 | 102 | 22 | 97 | .0 | 340 | 115 | 2.7 | 78 | 573 | .... |
| Aug. 18 | Aug. 29 | 90 | 66 | .73 | 29 | 1.4 | 77 | 14 | 60 | .0 | 240 | 69 | 4.0 | 40 | 380 | .... |
| Aug. 30 | Sept. 11 | 49 | 33 | .67 | 34 | .10 | 78 | 16 | 74 | a12.0 | 237 | 77 | 3.2 | 54 | 437 | .... |
| Sept. 12 | Sept. 21 | 43 | 34 | .79 | 36 | .03 | 84 | 19 | 106 | .0 | 305 | 97 | 2.3 | 96 | 570 | .... |
| Sept. 22 | Oct. 2 | 34 | 78 | 2.30 | 22 | .14 | 50 | 21 | 138 | .0 | 135 | 131 | 1.2 | 130 | 506 | .... |
| Oct. 3 | Oct. 16 | 188 | 131 | .70 | 23 | .12 | 66 | 13 | 66 | .0 | 200 | 74 | 4.0 | 54 | 373 | .... |
| Oct. 18 | Oct. 28 | 35 | 24 | .68 | 37 | .14 | 96 | 18 | 111 | .0 | 320 | 115 | 1.2 | 104 | 613 | .... |
| Oct. 29 | Nov. 7 | 34 | 17 | .50 | 31 | .14 | 109 | 22 | 114 | .0 | 360 | 125 | 1.2 | 106 | 664 | .... |
| Nov. 8 | Nov. 18 | 40 | 13 | .32 | 35 | .10 | 112 | 22 | 109 | .0 | 372 | 133 | .9 | 101 | 656 | .... |
| Nov. 19 | Dec. 5 | 33 | 18 | .54 | 34 | .10 | 87 | 21 | 114 | .0 | 367 | 132 | .3 | 90 | 594 | .... |
| Mean........ | | 313 | 194 | .75 | 35 | 1.4 | 92 | 16 | 86 | .0 | 294 | 108 | 3.0 | 67 | 534 | .... |
| Per cent of anhydrous residue.... | | ...... | ....... | ..... | 6.3 | .4 | 16.6 | 3.0 | 15.6 | 26.0 | ..... | 19.5 | .5 | 12.1 | ..... | .... |

a Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 1, 1906, to February 3, 1907, and from March 17 to November 18, 1907, by F. W. Bushong; from February 4 to March 16 and from November 19 to December 5, 1907, by Archie J. Weith.

TABLE 116.—*Turbidity of daily samples from Solomon River at Beloit, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | 25 | 14 | 7 | 13 | 47 | 15 | 45 | 440 | 150 | Broken. | 90 | 45 | 45 |
| 2 | 32 | 14 | 10 | 9 | 48 | 33 | 38 | 220 | 125 | 50 | 475 | 36 | 30 |
| 3 | 28 | 19 | 5 | 12 | 26 | 43 | 45 | 425 | 220 | 35 | 613 | 24 | 32 |
| 4 | 10 | 20 | 6 | 14 | 36 | 13 | 48 | 400 | 110 | 60 | ...... | 30 | 32 |
| 5 | 15 | 18 | 7 | 14 | ...... | 55 | 60 | ....... | 80 | 75 | ...... | 36 | 18 |
| 6 | ...... | 24 | ...... | 22 | 62 | 36 | 34 | ....... | 110 | 80 | ...... | 50 | ...... |
| 7 | 15 | 30 | ...... | 24 | 47 | 36 | 20 | 85 | 70 | 22 | ...... | 45 | ...... |
| 8 | 15 | 24 | ...... | 16 | 47 | 38 | 85 | 95 | 27 | 70 | 290 | 45 | ...... |
| 9 | 22 | 30 | ...... | 30 | 48 | 22 | 65 | 115 | 65 | 36 | 175 | 45 | ...... |
| 10 | 24 | 15 | ...... | 14 | ...... | 34 | 65 | 120 | 27 | 32 | 230 | 15 | ...... |
| 11 | ...... | 22 | ...... | 30 | 43 | 32 | 65 | 120 | 43 | 65 | 120 | 36 | ...... |
| 12 | ...... | 4 | ...... | 24 | 52 | 48 | 65 | 110 | 20 | 60 | 120 | 32 | ...... |
| 13 | 32 | 14 | ...... | 20 | 56 | 70 | 95 | 120 | 14 | 50 | 120 | 40 | ...... |
| 14 | 20 | ...... | 8 | ...... | 55 | 42 | 80 | 65 | 50 | 45 | 80 | 36 | ...... |
| 15 | 32 | 5 | 18 | 22 | 75 | 48 | 70 | 48 | 36 | 24 | 70 | 32 | ...... |
| 16 | 12 | 2 | 18 | 16 | 55 | 42 | 55 | 95 | 16 | 65 | 60 | 50 | ...... |
| 17 | 15 | 8 | ...... | 55 | 38 | 42 | 85 | 320 | 22 | 45 | ...... | 45 | ...... |
| 18 | 24 | 8 | ...... | 45 | 32 | ...... | 40 | 450 | 65 | 36 | 40 | 40 | ...... |
| 19 | 24 | 5 | ...... | 47 | 16 | 18 | 48 | 295 | 65 | 32 | 30 | 24 | ...... |
| 20 | 8 | 12 | 14 | 50 | 55 | 13 | 60 | 315 | 45 | 24 | 36 | 24 | ...... |
| 21 | ...... | 16 | 27 | 48 | 35 | 13 | 55 | 175 | 130 | 50 | 30 | 18 | ...... |
| 22 | 17 | 12 | 32 | 20 | 45 | 20 | 27 | 155 | 160 | 45 | 60 | 30 | ...... |
| 23 | 10 | 10 | 32 | 95 | 23 | 34 | 42 | 170 | 110 | 45 | 36 | 36 | ...... |
| 24 | 12 | 5 | 22 | 45 | 35 | 46 | 40 | 140 | 95 | 40 | 36 | 40 | ...... |
| 25 | 13 | 4 | 12 | 47 | 55 | 42 | 70 | 3,900 | 90 | 50 | 24 | 30 | ...... |
| 26 | 14 | 5 | 16 | 43 | 48 | 65 | 35 | 406 | 75 | 36 | 32 | 45 | ...... |
| 27 | 12 | 6 | 16 | 38 | 20 | 65 | 40,458 | 1,300 | 70 | 45 | 24 | 36 | ...... |
| 28 | 10 | 5 | 20 | 38 | 34 | 30 | 34,776 | 650 | 80 | 50 | 36 | 36 | ...... |
| 29 | 11 | 7 | ...... | 70 | 55 | 55 | 220 | 265 | 60 | 50 | 30 | 45 | ...... |
| 30 | 12 | 13 | ...... | 15 | 15 | 60 | 550 | 440 | 35 | 165 | 16 | ...... | ...... |
| 31 | 10 | 10 | ...... | 48 | ...... | 40 | ........ | 365 | 55 | .......... | 30 | ...... | ...... |
| Mean | 18 | 13 | 16 | 33 | 43 | 38 | 2,581 | 407 | 75 | 51 | 112 | 36 | ...... |

NOTE.—Turbidities over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

The results of tests of the waters of this river and its tributaries at points other than the sampling stations are presented in assays 13 to 21, Table 102 (p. 204), and analyses 9 to 11, Table 103 (p. 206). The water of Elm Creek, analysis 9, Table 103, is hard but treatable, and the water of Deer Creek, assay 13, Table 102, is like that of Elm Creek. Both of these waters are low in chlorides. The water of Beaver Creek, assay 14, Table 102, is much harder than that of Elm and Deer creeks. The water of South Fork of Solomon River at Morland is soft (assay 16, Table 102), but at Stockton (assay 17, Table 102) the sulphates have increased. Assay 18, Table 102, indicates that the water of the South Fork at Cawker does not differ greatly from that of the South Fork at Stockton, and that it is considerably harder than the water of the North Fork just above the confluence of the two forks at Cawker.

## REPUBLICAN RIVER BASIN.

### DESCRIPTION.

Republican River is of the plains, its headwaters being gathered far from the Rocky Mountains in the table-lands of northeastern Colorado.

The South Fork, which is here regarded as the continuation of the main stream, rises in Lincoln County, Colo., and flows northeastward to Benkelman, in Dundy County, Nebr., where it is joined by the North Fork, a stream that heads in Yuma County, Colo., and flows eastward. From Benkelman the main Republican holds an easterly course across the southern counties of Nebraska to Superior, south of which it passes into Jewell County, Kans. From the Kansas-Nebraska State line to Junction, where it unites with the Smoky Hill to form Kansas River, the Republican meanders southeastward, traversing 150 miles in covering an air-line distance of 90 miles.

Republican River has been estimated to be 100 miles long in Colorado, 200 miles in Nebraska, and somewhat less than 200 miles in Kansas. Its drainage comprises an aggregate of 25,840 square miles, of which 7,920 are in Colorado, 10,410 in Nebraska, and 7,500 in Kansas.

The channels of the several branches of the Republican in Colorado lie for the most part within the porous Tertiary deposits, but from the southern part of Yuma County northeastward the South Fork and the Arikaree, the principal tributary of the North Fork, have cut down to the Cretaceous beds.

The valley of the South Fork of the Republican at St. Francis, Kans., is known as the St. Francis Basin. During the summer of 1908 Charles S. Slichter and H. C. Wolff, of the United States Reclamation Service, made for the United States Geological Survey a careful study of the basin to determine to what extent irrigation farming might be developed from the underflow of the South Fork. Some of the salient conclusions arrived at are quoted here from Mr. Wolff's report on the experiments.[1] They are:

1. The source of the underflow is the precipitation in the drainage basin of the river.
2. The water-bearing gravel in the valley averages about 15 feet in thickness.
3. The water plane at St. Francis, Kans., slopes down the valley at the rate of 10.7 feet per mile.
4. The underflow of South Fork of Republican River moves at an average rate of 17 feet per day.
5. The rate of movement is, in general, much faster near the center of the valley than near its edges.
6. Better wells for irrigation can, in general, be sunk near the center of the valley than near its edges.
7. There is no danger that the underground water in the valley will be exhausted by pumping.
8. The water-bearing gravel contains enough large material to permit the use of a well strainer having openings as large as 1 inch long by three-sixteenths of an inch wide.
9. Except perhaps in a few localities along the northwestern side of the valley the quantity of dissolved salts in the ground water is not large enough to be injurious to plant life.

[1] Water-Supply Paper U. S. Geol. Survey No. 258, 1911, p. 119.

Throughout Nebraska the drainage area of Republican River is gently rolling or level, and most of the western part, except the immediate stream valley, is given over to cattle raising. The soil of the valley is very fertile and large quantities of alfalfa, hay, and grains are grown. At some points in the western part of the area the entire flow of the stream is diverted for irrigation.[1]

The chief tributaries received by the Republican in Nebraska are, from the north, Frenchman River, Red Willow and Medicine creeks, and from the south, Sappa and Prairie Dog creeks. The northern tributaries lie mostly within Nebraska, the southern within Kansas.

Frenchman Creek has its source in springs from the Tertiary and in its upper course has cut deep steep-walled canyons, but farther down, where the slopes are gentler, it has a wider valley which is eroded to the Pierre clay. Near its mouth the stream is shallow and from 75 to 100 feet wide. It flows over a sandy bed in which there are small sandbars and islands.

Red Willow and Medicine creeks rise in canyons near Platte River in Lincoln County, Nebr., and carry their small volume of water to Republican River through deep narrow valleys in a nearly level upland.

Sappa Creek rises in Sherman County, Kans., flows northeastward, and joins Republican River near Orleans, Nebr. Its principal tributary, Beaver Creek, drains a considerable area. Both Sappa and Beaver creeks lie for the most part in the Tertiary deposits, but as the rocks of that system are thin in northwestern Kansas, they have cut their channels almost to its base in their upper reaches and quite to the Cretaceous farther down, so that they draw upon the underground water from the Tertiary. The streams alternat ly flow and disappear beneath their beds in part of their course through Kansas, but in Nebraska their flow is constant.

Prairie Dog Creek rises in the eastern part of Sherman County and flows a northeasterly direction through Thomas County, the northwest corner of Sheridan County, the southeast corner of Decatur County, diagonally across Norton County, and the northeast corner of Phillips County, entering Republican River south of Republican Junction, in Harlan County, Nebr.

The principal tributaries of Republican River wholly within Kansas are White Rock and Buffalo creeks, both of which enter from the west and throughout their courses flow through the Cretaceous. Buffalo Creek receives the drainage of the large Jamestown salt marsh and thereby increases the salinity of Republican River. The Kansas tributaries of the river from the east are unimportant, save only Salt Creek, which comes in at Lawrenceburg, and which carries the drainage of Tuthill salt marsh.

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[1] Stevens, J. C., Surface waters of Nebraska: Water-Supply Paper U. S. Geol. Survey No. 230, 1909, pp. 176–177.

The Republican flows over an alluvium of its own deposition, and its valley bottom lies from 200 to 400 feet below the bordering table-lands and loess of the plains. The stream is for the most part shallow and relatively wide, its sandy bed lying between low sandy banks except at places where the river cuts into bordering terraces, where the banks are higher and precipitous.

Throughout its course in Nebraska the stream flows in Cretaceous deposits and is supplied by spring-fed tributaries. In the western counties, where rainfall is small and direct run-off rapid, the river bed is often dry, as for example, in midsummer, immediately above the mouths of Buffalo, Rock, and Frenchman creeks, but these streams revive the flow of the river below their mouths. Such alternating dryness and flow extend as far east as Superior during droughts, but only once in 12 years has the river ceased to flow at Red Cloud and Superior.

There is excellent evidence that under Phelps and Kearney counties, Nebr., an underflow from Platte River sets toward Republican Valley. Platte River in these counties has an abundant supply of water in the basal beds of the alluvium near the stream. The seepage of the water from Platte Valley into that of the Republican is rendered possible because Platte River Valley has a considerably greater altitude than Republican River Valley and because between the two rivers the great sheet of materials lying between the loess and the top of the impervious Pierre shale is pervious.

In Kansas the Republican Valley averages 2 miles wide and is bordered on each side by bluffs 100 to 150 feet high. The channel is in the Cretaceous rocks to Clay County, where the river enters the Permian, in which it continues to its mouth.

The discharge of Republican River at Junction is shown in the following table:

TABLE 117.—*Mean monthly discharge of Republican River at Junction, Kans., for period July 1, 1895, to October 31, 1905, inclusive.*

[Drainage area, 25,800 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 1,985 | 325 | 713 |
| February | 6,230 | 280 | 1,010 |
| March | 13,500 | 504 | 1,500 |
| April | 12,300 | 375 | 1,250 |
| May | 47,520 | 325 | 2,830 |
| June | 44,280 | 290 | 3,180 |
| July | 37,500 | 75 | 3,000 |
| August | 25,000 | 20 | 1,490 |
| September | 10,500 | 20 | 704 |
| October | 5,150 | 35 | 515 |
| November | 1,480 | 63 | 469 |
| December | 2,443 | 173 | 554 |
| The period | 47,520 | 20 | 1,430 |

## QUALITY OF WATER.

### REPUBLICAN RIVER AT JUNCTION.

The United States Geological Survey maintained a daily sampling station on Republican River at Junction from November 26, 1906, to July 27, 1907. J. H. Rathert was collector. A record of the analyses of the composite samples obtained at this station appears in Table 118.

The water may be classed as a calcic alkaline water of considerable temporary and permanent hardness. The chlorides fluctuate a good deal, but are never very high. A comparison of the mean of Table 118 with the means of Tables 111, 115, and 130 shows that the Republican carries almost exactly the same amount of bicarbonates as Solomon River, less than Saline River, and more than Big Blue River. It is evident, too, that the sulphates and chlorides of the Republican are far less than those of the Saline, about half as great as those of the Solomon, and about one-third greater than those of the Big Blue. This is what would be expected from a knowledge of the streams, for the Saline receives the largest contribution of saline and gypsiferous waters from the Dakota, the Solomon next, the Republican next, and Big Blue River the least.

The result of a test of the water of the Republican River above Junction is given in analysis 19, Table 103. The figures do not differ greatly from those for the composite samples of January 17–26 and January 27–February 5, Table 117, though the chlorides are considerably higher than in any analysis given in that table.

The turbidity of the daily samples from Republican River at Junction is recorded in Table 119. The river was very turbid all the time it was under observation, especially during June, when there were but 7 samples that had a turbidity of less than 1,000. During July, too, the river was remarkably turbid, but the record for the month is very much broken. There were 237 turbidity readings, a little more than 6 per cent of which were less than 50, nearly 84 per cent were over 100, and a trifle over 13 per cent were over 1,000.

TABLE 118.—*Analyses of water from Republican River at Junction, Kans.*

[Drainage area 25,840 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. | Mean gage height (feet).[a] | Mean discharge (cubic feet per second). | Run-off per square mile (cubic feet per second). | Suspended matter (tons per 24 hours). | Dissolved matter (tons per 24 hours). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | | | | | | |
| Nov. 26 | Dec. 5 | 325 | 223 | 0.69 | 39 | 1.1 | 68 | 14 | 68 | 0.0 | 338 | 47 | 0.7 | 29 | 397 | 6.1 | 830 | 0.032 | 500 | 890 |
| Dec. 6 | Dec. 15 | 305 | 177 | .58 | ........ | 1.2 | 74 | 43 | 52 | .0 | 330 | 48 | 2.0 | 27 | 399 | 6.0 | 800 | .031 | 380 | 860 |
| Dec. 16 | Dec. 25 | 152 | 109 | .72 | 46 | .8 | 79 | 19 | 56 | [b] 11 | 320 | 69 | 2.6 | 37 | 436 | 5.6 | 720 | .028 | 210 | 850 |
| | 1907. | | | | | | | | | | | | | | | | | | | |
| Dec. 26 | Jan. 4 | 320 | 238 | .74 | 39 | 2.4 | 78 | 10 | 51 | .0 | 372 | 58 | .9 | 36 | 518 | 6.3 | 890 | .034 | 570 | 1,240 |
| 1907. | | | | | | | | | | | | | | | | | | | | |
| Jan. 6 | Jan. 16 | 257 | 177 | .69 | 42 | 3.5 | 71 | 22 | 56 | [b] 8.9 | 298 | 59 | 4.4 | 40 | 419 | 5.7 | 740 | .029 | 350 | 840 |
| Jan. 17 | Jan. 26 | 108 | 74 | .68 | 62 | .6 | 82 | 7.2 | 75 | [b] 7.7 | 338 | 70 | 3.3 | 35 | 471 | 5.7 | 740 | .029 | 150 | 940 |
| Jan. 27 | Feb. 5 | 55 | 56 | 1.02 | 65 | 1.2 | 82 | 18 | 83 | [b] 18 | 340 | 59 | 1.3 | 35 | 485 | —5.7 | 740 | .029 | 110 | 970 |
| Feb. 6 | Feb. 15 | 205 | 161 | .78 | 57 | .26 | 71 | 17 | 64 | [b] 10 | 294 | 56 | 1.5 | 30 | 419 | 6.0 | 800 | .031 | 350 | 900 |
| Feb. 16 | Feb. 26 | 925 | 817 | .88 | 145 | .20 | 55 | 6.0 | 44 | .0 | 243 | 37 | 2.4 | 14 | 429 | 7.1 | 1,150 | .044 | 2,540 | 1,330 |
| Feb. 27 | Mar. 8 | 526 | 681 | 1.30 | 79 | .56 | 65 | 14 | 35 | .0 | 260 | 45 | 3.1 | 20 | 423 | 6.6 | 980 | .038 | 1,800 | 1,120 |
| Mar. 10 | Mar. 20 | 446 | 468 | 1.05 | 36 | .18 | 68 | 15 | 58 | .0 | 277 | 53 | 2.1 | 31 | 382 | 6.5 | 950 | .037 | 1,200 | 980 |
| Mar. 21 | Mar. 30 | 200 | 198 | .99 | 38 | 2.5 | 68 | 7.3 | 59 | .0 | 305 | 45 | 1.1 | 28 | 405 | 6.3 | 890 | .034 | 480 | 970 |
| Mar. 31 | Apr. 9 | 185 | 157 | .85 | 38 | 2.5 | 73 | 11 | 59 | .0 | 318 | 55 | .3 | 25 | 396 | 6.1 | 830 | .032 | 350 | 890 |
| Apr. 10 | Apr. 20 | 144 | 122 | .85 | 36 | 1.8 | 76 | 6.3 | 55 | [b] 7 | 320 | 56 | 1.5 | 32 | 407 | 5.9 | 780 | .030 | 260 | 860 |
| Apr. 21 | Apr. 30 | 146 | 119 | .81 | 39 | 1.5 | 79 | 19 | 62 | .0 | 327 | 60 | 1.2 | 33 | 419 | 5.8 | 760 | .029 | 240 | 860 |
| May 1 | May 10 | 131 | 112 | .85 | 39 | 2.2 | 70 | 12 | 54 | .0 | 312 | 55 | 1.7 | 31 | 398 | 5.9 | 780 | .030 | 240 | 840 |
| May 12 | May 21 | 138 | 132 | .96 | 44 | 1.0 | 78 | 7.9 | 57 | .0 | 330 | 58 | 1.6 | 32 | 427 | 5.9 | 780 | .030 | 280 | 900 |
| May 22 | May 31 | 120 | 157 | 1.31 | 43 | 1.0 | 80 | 4.5 | 67 | [b] 5.0 | 330 | 65 | 1.4 | 37 | 441 | 6.0 | 800 | .031 | 340 | 950 |
| June 1 | June 10 | 1,966 | 1,548 | .79 | 35 | 4 | 49 | 13 | 45 | .0 | 228 | 36 | 7.5 | 21 | 312 | 6.4 | 920 | .036 | 3,850 | 780 |
| June 11 | June 21 | 3,760 | 2,650 | .70 | 41 | 9 | 48 | 19 | 24 | .0 | 195 | 36 | 11 | 15 | 290 | 7.0 | 1,100 | .042 | 7,870 | 860 |
| June 22 | July 1 | 1,485 | 1,008 | .68 | 43 | 6 | 65 | 12 | 50 | .0 | 242 | 40 | 5.5 | 20 | 336 | 6.3 | 890 | .034 | 2,420 | 810 |
| July 2 | July 16 | 2,070 | 1,467 | .71 | 39 | 2.0 | 64 | 16 | 53 | .0 | 255 | 49 | 8 | 25 | 345 | 5.9 | 780 | .030 | 3,090 | 730 |
| July 18 | July 27 | 3,350 | 2,450 | .73 | 42 | 7 | 46 | 13 | 61 | .0 | 177 | 21 | 3.5 | 19 | 262 | 7.0 | 1,100 | .042 | 7,270 | 780 |
| July 28 | Aug. 30 | 1,300 | 1,006 | .77 | 33 | 1.8 | 65 | 14 | 62 | .0 | 198 | 62 | 3.8 | 47 | 399 | ........ | ........ | ........ | ........ | ........ |
| Aug. 31 | Sept. 10 | 45 | 55 | 1.22 | 44 | .07 | 75 | 21 | 75 | [b] 7.0 | 277 | 77 | 1.5 | 51 | 449 | 5.3 | 660 | .026 | ........ | 800 |
| Mean.......... | | 746 | 574 | .85 | 48 | 2.2 | 69 | 14 | 57 | .0 | 295 | 53 | 3.0 | 30 | 402 | ........ | 850 | ........ | 1,515 | 915 |
| Per cent of anhydrous residue.... | | ........ | ........ | ........ | 11.4 | .5 | 16.4 | 3.3 | 13.5 | 34.5 | ........ | 12.6 | .7 | 7.1 | ........ | ........ | ........ | ........ | ........ | ........ |

[a] Gaging station at Clay Center, Kans.

[b] Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from November 26, 1906, to February 5, 1907, and from March 21 to September 10, 1907, by F. W. Bushong; from February 6 to March 20, 1907, by Archie J. Weith.

TABLE 119.—*Turbidity of daily samples from Republican River at Junction, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | 1906. | | 1907. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
| 1 | ........ | 295 | 372 | 60 | 473 | 180 | 130 | 1,530 | 2,580 | ........ | 36 |
| 2 | ........ | 267 | 435 | 120 | 440 | 210 | 135 | 3,000 | ........ | ........ | 32 |
| 3 | ........ | 265 | 535 | 60 | 406 | 160 | 115 | 2,898 | ........ | ........ | 30 |
| 4 | ........ | 240 | 475 | 45 | 385 | 210 | 125 | 2,898 | ........ | ........ | 65 |
| 5 | ........ | 300 | ........ | 48 | 430 | 155 | 90 | 2,315 | ........ | ........ | 40 |
| 6 | ........ | 370 | 870 | 38 | 632 | 145 | 155 | 1,530 | 1,800 | ........ | 36 |
| 7 | ........ | 395 | 525 | 45 | 732 | 180 | 140 | 1,530 | 1,750 | ........ | 70 |
| 8 | ........ | 248 | 375 | 50 | 666 | 200 | 150 | 1,600 | 1,000 | ........ | 32 |
| 9 | ........ | 357 | ........ | 120 | ........ | 200 | 150 | 1,000 | 1,264 | ........ | 24 |
| 10 | ........ | 290 | 150 | 160 | 650 | 110 | 120 | 1,360 | 833 | ........ | 36 |
| 11 | ........ | 290 | 140 | 263 | 450 | 135 | ........ | 5,796 | 650 | ........ | ........ |
| 12 | ........ | 270 | 155 | 280 | 430 | 165 | 130 | 6,000 | 500 | ........ | ........ |
| 13 | ........ | 265 | 110 | 310 | ........ | ........ | 115 | 6,600 | 406 | ........ | ........ |
| 14 | ........ | 290 | 135 | 450 | 765 | 135 | 200 | ........ | ........ | ........ | ........ |
| 15 | ........ | 277 | 70 | 336 | 450 | 125 | 140 | 4,800 | ........ | ........ | ........ |
| 16 | ........ | 215 | 36 | 308 | 400 | 180 | 150 | 4,080 | 302 | ........ | ........ |
| 17 | ........ | 294 | 50 | 440 | 332 | 115 | 180 | 3,600 | ........ | ........ | ........ |
| 18 | ........ | 150 | 55 | 473 | 320 | 220 | 150 | 2,000 | ........ | ........ | ........ |
| 19 | ........ | 75 | 110 | 520 | 315 | 125 | 120 | 2,000 | ........ | ........ | ........ |
| 20 | ........ | 90 | 160 | 1,530 | 370 | 130 | 75 | 1,732 | ........ | ........ | ........ |
| 21 | ........ | 125 | 120 | 1,464 | 320 | 160 | 115 | 1,000 | ........ | ........ | ........ |
| 22 | ........ | 135 | 130 | 1,800 | 260 | 105 | 75 | 966 | ........ | ........ | ........ |
| 23 | ........ | 155 | 160 | 1,800 | 270 | 115 | 125 | 900 | ........ | ........ | ........ |
| 24 | ........ | 120 | 150 | ........ | 160 | 200 | 115 | 866 | ........ | 650 | ........ |
| 25 | ........ | 160 | 80 | 900 | 160 | 150 | 90 | 866 | ........ | 165 | ........ |
| 26 | 270 | 165 | 60 | 700 | 210 | 140 | 115 | 700 | ........ | 105 | ........ |
| 27 | 415 | 242 | 50 | 532 | 110 | 175 | 90 | 650 | ........ | 110 | ........ |
| 28 | 470 | 195 | 47 | 562 | 150 | 150 | 120 | 613 | ........ | 90 | ........ |
| 29 | 410 | 200 | 100 | ........ | 155 | 150 | 55 | 3,900 | ........ | 65 | ........ |
| 30 | 340 | 270 | 55 | ........ | 200 | 120 | 210 | 2,800 | ........ | 125 | ........ |
| 31 | ........ | 320 | 40 | ........ | 215 | ........ | 210 | ........ | ........ | 90 | ........ |
| Mean. | 381 | 236 | 198 | 497 | 374 | 157 | 130 | 2,398 | 1,108 | 175 | 40 |

NOTE.—July averages: July 2 to 5, 4,590; July 17 to 22, 3,900; July 23 to 25, 2,640; July 26 to 27, 3,000; July 28 to 29, 2,800. Turbidities over 50 were determined by a Jackson turbidimeter, and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

## SAPPA CREEK.

A sampling station was established on Sappa Creek in Oberlin but was soon discontinued because it became evident that the flow of the creek there was intermittent. The analyses, Table 120, show the water to be very high in bicarbonates, the reason being that at the time the samples were taken the creek contained little else than ground water from the Tertiary.

TABLE 120.—*Analyses of water from Sappa Creek at Oberlin, Kans.*

[Drainage area, 1,180 square miles (estimated). Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Nov. 28 | Dec. 7 | 32 | 23 | 0.72 | 41 | [a]1.0 | 93 | 23 | 77 | 0.0 | 539 | 7.2 | 4.4 | 16 | 490 |
| Dec. 8 | Dec. 17 | 26 | 18 | .69 | 46 | 1.2 | 102 | 23 | 68 | .0 | 605 | 8.8 | 3.5 | 18 | 542 |
| Dec. 18 | Dec 27 | 28 | 12 | .43 | 45 | .7 | 123 | 36 | 69 | .0 | 685 | 6.8 | 4.4 | 20 | 594 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 28 | Jan. 9 | 9 | 5.9 | .66 | 49 | .8 | 87 | 21 | 64 | [b]7.0 | 406 | 21 | 3.5 | 12 | 409 |
| Mean | | 24 | 15 | .62 | 45 | .92 | 101 | 26 | 70 | .0 | 562 | 11 | 4.0 | 16 | 509 |
| Per cent of anhydrous residue | | ..... | ..... | ...... | 8.2 | .2 | 18.3 | 4.7 | 12.7 | 50.2 | ...... | 2.0 | .7 | 3.0 | ...... |

[a] Al=0.3. [b] Abnormal; computed as $HCO_3$ in the average.

NOTE.—Samples collected by C. S. Maddox; analyses by F. W. Bushong.

### PRAIRIE DOG CREEK.

A daily sampling station was maintained on Prairie Dog Creek from December 6, 1906, to December 5, 1907. Frank Swart and A. H. Mischke were collectors.

A record of the analyses of the composite samples is presented in Table 121.

The water of the creek may be classed as calcic alkaline. Inasmuch as calcium and the bicarbonates are high and sulphates are low, the water of Prairie Dog Creek has high temporary and low permanent hardness. On the assumption that high turbidity generally denotes high stage of the creek, it appears that the bicarbonates in the creek water commonly fall when the creek is high and rise when it is low. This means that the bicarbonates, being more abundant in the ground water than in the surface water, are diluted in times of heavy rains and melting snows, for then surface waters form a large percentage of the water flowing in the creek. The total dissolved solids rise and fall with the stage of the creek for the same reason.

During the six months from December 5 to June 6, inclusive, the turbidity of Prairie Dog Creek (Table 122) was low. On only six days in this period did it exceed 100, and on only 37 days was it greater than 50. The turbidity of the creek from March 20 to 25 was high, and also from June 7 to September 4. Thereafter the turbidity fluctuated, but had a tendency to be higher than it was from December, 1906, to June, 1907. Three hundred and one turbidity readings were made. Nearly 44 per cent of the samples had a turbidity of less than 50 and more than 38 per cent had a turbidity of 100 or more. Changes in turbidity were very sudden, as from 180 on June 9 to 1,464 on June 10, and from 255 on July 13 to 1,932 on July 14. The lowest observed turbidity, 3, occurred on January 15 and 16; the highest, 14,400, was recorded on June 25. The coefficients of fineness of the several composite samples (Table 121) are rather high, and indicate that the suspended matter is fairly coarse.

TABLE 121.—*Analyses of water from Prairie Dog Creek at Long Island, Kans.*

[Drainage area (estimated), 900 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Dec. 5 | Dec. 14 | 40 | 31 | 0.78 | 33 | 0.20 | 87 | 19 | 31 | 0.0 | 386 | 13 | 0.3 | 9.0 | 355 |
| Dec. 15 | Dec. 25 | 13 | 11 | .85 | 37 | .40 | 92 | 19 | 35 | [a]12 | 422 | 16 | .5 | 12 | 399 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 26 | Jan. 4 | 23 | 16 | .70 | 43 | 1.2 | 79 | 9.5 | 38 | [a]12 | 340 | 31 | 4.2 | 8.0 | 335 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 5 | Jan. 15 | 13 | 12 | .92 | 38 | .8 | 92 | 18 | 36 | [a]12 | 390 | 15 | 4.8 | 10 | 379 |
| Jan. 16 | Jan. 26 | 8 | 76 | .95 | 38 | .6 | 94 | 18 | 42 | ...... | ..... | 20 | 1.3 | ...... | 403 |
| Jan. 27 | Feb. 6 | 11 | 14 | 1.27 | 59 | 1.0 | 96 | 17 | 38 | [a]18 | 435 | 20 | 1.1 | 14 | 430 |
| Feb. 7 | Feb. 16 | 31 | 32 | 1.03 | 49 | .02 | 52 | 18 | 46 | .0 | 359 | 16. | 1.2 | 7.2 | 355 |
| Feb. 17 | Mar. 2 | 60 | 58 | .97 | 59 | .20 | 71 | 14 | ..... | .0 | 308 | 13 | 1.5 | 7.9 | 339 |
| Mar. 3 | Mar. 13 | 47 | 43 | .91 | 64 | .52 | 81 | 15 | 37 | .0 | 353 | 14 | .7 | 8.0 | 379 |
| Mar. 14 | Mar. 23 | 101 | 99 | .98 | 30 | 2.0 | 82 | 18 | 34 | .0 | 367 | 11 | .9 | 8.2 | 337 |
| Mar. 24 | Apr. 5 | 54 | 41 | .76 | 34 | 1.0 | 88 | 8.4 | 31 | .0 | 403 | 8.3 | .5 | 7.1 | 364 |
| Apr. 6 | Apr. 17 | 39 | 33 | .85 | 30 | 3.4 | 88 | 8.1 | 32 | .0 | 412 | 9.2 | 1.2 | 8.8 | 362 |
| Apr. 18 | May 4 | 29 | 22 | .76 | 32 | 1.6 | 88 | 17 | 37 | .0 | 384 | 11 | 1.1 | 11 | 354 |
| May 5 | May 16 | 29 | 22 | .76 | 36 | 2.0 | 89 | 6.7 | 33 | .0 | 387 | 12 | 1.6 | 9 | 358 |
| May 17 | May 26 | 61 | 52 | .85 | 39 | 1.2 | 89 | 5.2 | 39 | .0 | 415 | 9.1 | 3.5 | 10 | 389 |
| May 27 | June 6 | 53 | 41 | .77 | 39 | .8 | 90 | 22 | 39 | .0 | 395 | 8.6 | 4.1 | 11 | 375 |
| June 8 | June 19 | 672 | 467 | .69 | 20 | 12 | 58 | 12 | 46 | .0 | 285 | 14 | 12 | 9 | 337 |
| June 21 | July 3 | 2,435 | 1,568 | .64 | 49 | 5 | 54 | 11 | 32 | .0 | 250 | 13 | 10 | 7 | 289 |
| July 4 | July 14 | 610 | 416 | .68 | 61 | 5 | 80 | 19 | 43 | [a]7 | 362 | 16 | 7.5 | 11 | 385 |
| July 15 | July 28 | 1,506 | 1,116 | .74 | 55 | 7 | 55 | 12 | 33 | .0 | 240 | 16 | 8 | 5 | 290 |
| July 29 | Aug. 7 | 248 | 175 | .70 | 44 | 2 | 73 | 18 | 38 | .0 | 335 | 15 | 4.0 | 14 | 351 |
| Aug. 8 | Aug. 17 | 1,730 | 1,238 | .72 | 38 | 10 | 62 | 18 | 35 | .0 | 278 | 15 | 6 | 10 | 426 |
| Aug. 24 | Sept 4 | 269 | 215 | .80 | 32 | .08 | 60 | 15 | 43 | .0 | 250 | 16 | 8.0 | 7.5 | 279 |
| Sept. 5 | Sept. 15 | 100 | 100 | 1.00 | 32 | .03 | 67 | 17 | 33 | .0 | 290 | 16 | 4.0 | 9 | 301 |
| Sept. 26 | Oct. 6 | 224 | 213 | .95 | 20 | .12 | 54 | 18 | 35 | .0 | 235 | 16 | 1.2 | 7.3 | 236 |
| Oct. 7 | Oct. 16 | 93 | 99 | 1.07 | 28 | .50 | 51 | 14 | 29 | .0 | 202 | 18 | 4.5 | 6.5 | 234 |
| Oct. 17 | Oct. 30 | 71 | 74 | 1.04 | 35 | .20 | 43 | 13 | 32 | .0 | 245 | 15 | 3.5 | 6.5 | 268 |
| Nov. 1 | Nov. 12 | 189 | 165 | .87 | 25 | 1.2 | 54 | 14 | 30 | .0 | 278 | 14 | 3.8 | 8.5 | 281 |
| Nov. 13 | Nov. 22 | 85 | 71 | .84 | 29 | .16 | 69 | 14 | 25 | .0 | 270 | 15 | 3.2 | 7.0 | 274 |
| Nov. 23 | Dec. 4 | 283 | 170 | .60 | 30 | .12 | 71 | 19 | 36 | .0 | 300 | 14 | 3.5 | 9.0 | 307 |
| Mean........ | | 304 | 221 | .85 | 39 | 2.0 | 74 | 15 | 36 | .0 | 334 | 15 | 3.6 | 8.9 | 339 |
| Per cent of anhydrous residue.... | | ...... | ........ | ..... | 10.7 | .8 | 20.6 | 4.2 | 10.0 | 46.0 | ..... | 4.2 | 1.0 | 2.5 | .... |

[a] Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 5, 1906, to February 6, 1907, and from March 14 to December 4, 1907, by F. W. Bushong; from February 7 to March 13, 1907, by Archie J. Weith.

TABLE 122.—*Turbidity of daily samples from Prairie Dog Creek, at Long Island, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | ...... | 20 | 10 | 27 | 70 | 20 | 34 | 650 | 255 | ...... | 30 | 90 | 265 |
| 2 | ...... | 28 | 6 | 60 | ...... | 34 | 65 | 650 | 275 | 80 | 30 | 150 | 370 |
| 3 | ...... | 24 | 7 | 60 | 45 | ...... | 65 | 440 | 190 | 55 | 430 | 230 | 260 |
| 4 | ...... | 40 | ...... | ...... | 70 | 20 | 60 | 580 | 200 | 75 | 195 | 220 | 245 |
| 5 | 36 | 16 | 13 | 65 | 38 | 22 | 65 | 532 | 242 | ...... | 420 | 235 | ...... |
| 6 | 20 | 24 | 12 | 50 | 40 | 22 | 72 | 485 | 190 | ...... | 240 | ...... | ...... |
| 7 | 30 | 22 | 38 | 36 | 45 | 20 | ........ | 562 | 220 | ...... | 240 | ...... | ...... |
| 8 | 24 | ...... | 15 | 60 | 26 | 22 | 140 | 430 | 200 | ...... | 180 | 240 | ...... |
| 9 | 37 | 15 | 18 | 40 | 38 | 30 | 180 | 412 | 520 | ...... | 140 | 270 | ...... |
| 10 | 26 | 12 | 10 | 34 | 36 | 34 | 1,464 | 510 | 302 | ...... | 80 | 70 | ...... |
| 11 | 40 | 7 | 16 | 38 | ...... | 38 | ........ | 412 | 150 | ...... | 50 | 100 | ...... |
| 12 | 40 | 4 | 12 | 55 | 40 | 50 | 933 | 600 | 406 | ...... | 50 | 280 | ...... |
| 13 | 40 | 16 | 48 | 36 | ...... | ...... | 833 | 255 | 550 | ...... | 45 | 100 | ...... |
| 14 | 30 | 8 | 20 | 36 | 68 | 24 | 532 | 1,932 | 933 | ...... | 45 | 120 | ...... |
| 15 | 16 | 3 | 65 | 55 | 42 | ...... | 406 | 1,866 | ........ | ...... | 50 | 80 | ...... |
| 16 | 20 | 3 | 65 | 36 | 27 | 34 | 500 | 4,080 | ........ | ...... | 50 | 50 | ...... |
| 17 | ...... | 7 | 105 | 60 | 27 | 35 | ........ | 3,372 | ........ | ...... | 50 | 36 | ...... |
| 18 | 12 | ...... | 70 | 47 | 27 | 50 | 833 | 2,040 | 1,600 | ...... | 45 | 45 | ...... |
| 19 | 10 | 7 | 65 | 48 | ...... | 60 | 900 | 966 | 1,936 | ...... | ...... | 40 | ...... |
| 20 | 10 | 10 | ...... | 473 | 27 | 55 | ........ | ........ | 1,100 | ...... | 60 | 130 | ...... |
| 21 | 10 | 14 | ...... | 190 | 45 | 65 | 650 | 1,000 | 1,100 | ...... | ...... | 120 | ...... |
| 22 | 12 | 10 | 40 | 110 | ...... | 68 | 866 | ........ | 765 | 35 | 24 | 125 | ...... |
| 23 | 14 | 8 | 27 | 50 | ...... | 70 | 680 | 500 | 833 | 120 | 100 | 332 | ...... |
| 24 | 12 | 5 | ...... | 115 | 43 | 70 | 650 | 473 | 632 | 70 | 24 | 325 | ...... |
| 25 | 15 | 5 | ...... | 185 | ...... | 70 | 14,400 | ........ | 412 | 130 | 90 | 330 | ...... |
| 26 | 13 | 10 | 90 | ...... | 22 | 65 | ........ | ........ | 350 | 130 | ...... | 310 | ...... |
| 27 | 11 | 8 | 65 | ...... | 34 | 55 | ........ | 425 | 350 | 320 | 100 | 310 | ...... |
| 28 | 10 | 10 | 36 | 47 | 14 | ...... | 3,900 | 340 | 95 | 245 | 135 | 45 | ...... |
| 29 | 27 | 7 | ...... | 48 | ...... | 45 | 1,462 | 332 | 260 | 200 | ...... | 40 | ...... |
| 30 | 27 | 8 | ...... | 70 | ...... | 36 | ........ | 295 | 317 | ...... | 80 | ...... | ...... |
| 31 | 28 | 20 | ...... | 47 | ...... | 34 | ........ | 285 | 332 | ...... | ...... | ...... | ...... |
| Mean | 22 | 13 | 37 | 78 | 39 | 42 | 129 | 904 | 526 | 133 | 115 | 164 | 285 |

NOTE.—August average: August 8 to 17, 1,730. September averages: September 5 to 15, 100; September 16 to 25, 160. Turbidities over 50 were determined by a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

## OTHER TRIBUTARIES.

No test was made of the water of the North Fork, but the waters of the Arikaree and of the South Fork were examined.

Arikaree Fork is shown by analysis 17, Table 103 (p. 206), to carry alkaline-saline water of high permanent hardness, very different from the water of the South Fork, assay 27, Table 102, which carries but a trace of sulphates and is an alkaline water. The water of the South Fork is like that of Beaver Creek, assay 27, Table 102, like that of Sappa Creek, Table 120, and like that of Prairie Dog Creek, Table 121. As these three creeks and the South Fork derive most of their water from the Tertiary deposits, it is not surprising that their waters, like the ground water from rocks of that system, are characterized by bicarbonates and carry a light burden of sulphates. The reason why the water of Arikaree Fork, which, like the others, heads in the Tertiary and through only part of its course has cut down to the Cretaceous floor, is dissimilar to the waters of these other streams, remains to be determined by future investigators.

No study has been made of the quality of the waters of the western Nebraska streams that enter Republican River. The water of White Rock Creek, the first important tributary that the river receives in Kansas below Prairie Dog Creek, is shown by assay 29, Table 102, to be high in sulphates, doubtless derived from the Cretaceous rocks through which the stream flows.

A test of the waters of Buffalo Creek, which enter Republican River northeast of Yuma, is recorded in assay 30, Table 102. The water of this creek is high in sulphates and chlorides, both of which are derived from salt springs and marshes on sections 11, 24, and 25 in Vicksburg Township, Jewell County, from the Jamestown Marsh northwest of Jamestown, and from Little Marsh northwest of Yuma. These marshes and springs originate in the saliferous and gypsiferous shales of the Dakota sandstone.

The drainage of Tuthill salt marsh enters Republican River through Salt Creek at Lawrenceburg; no test was made of the water of Salt Creek.

## KANSAS RIVER.

### DESCRIPTION.

Kansas River as such is a comparatively short stream, winding in a general easterly direction through a remarkably beautiful and fertile valley from the confluence of Republican and Smoky Hill rivers at Junction to Kansas City, Kans., where it unites with Missouri River.

From Junction to its mouth the course of Kansas River lies wholly within the Pennsylvanian rocks[1] and the stream is lined with bluffs that vary greatly in height. In places they are only 50 to 75 feet above the river, although to the east and to the west they rise much higher. This peculiar variation in the altitude of the bluffs is due to the fact that they owe their existence to a series of limestones which protect them from erosion and which have a western dip. Thus it happens that a limestone capping a bluff rises from west to east, the bluff gradually increasing in height until it reaches a place where erosive agencies have cut through the limestone. Here the height of the bluffs decreases suddenly, but increases gradually again to the eastward as another capping limestone rises toward the east. At Eudora, Lawrence, and Topeka the bluffs are low and rise to the east, while to the west are found the high escarpments of the overlying limestones which slope westward. Disregarding the channels cut by the lateral tributaries, the bluffs of the Kansas from Kansas City to Junction may be likened to a series of great steps, the treads of which dip westward until they reach positions much nearer the water level of the river than they do farther east. The

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[1] Kansas Univ. Geol. Survey, vol. 1, pp. 203–209.

risers in this great stairway are the escarpments which, facing eastward, mark the eastern outcroppings of the successive limestone systems.

Westward from Topeka a few miles the limestone beds are thinner and are moderately close together. Moreover, the vertical erosion of the river has exceeded the general erosion of the country, so that a large number of limestone beds are worn through by the river without being removed from the surface of the country. The bluffs are higher than downstream in the valley, but the valley maintains its width so that the bluff lines are well marked and their faces are composed of numerous little terraces, each of which is produced by one of the thinner limestone systems.

At only a few places in the river channel from Junction to Kansas City can limestone ledges be observed, for they have been entirely covered by the filling-in process incident to base leveling. Borings at Lawrence by the water company show that certain limestones and sandstones existing along the banks of the river have been worn away and that the depth of the river valley at one time was 50 or 60 feet greater than it now is. The gravels in the lower portions of the alluvium are much coarser than in the upper, for the old river channel was filled in first with coarse gravel and then with finer. There is no doubt but that in the youthful period of the Kansas many cataracts and falls occurred in the river from its mouth as far west as the western limits of the Pennsylvanian. The Oread limestone and the underlying shale caused huge cataracts and falls. High bluffs at Kansas City, composed of heavy beds of limestones with shale beds beneath, probably produced similar falls in Missouri River at or below Kansas City.

As the headwaters of the river originate in the plains, it is not subject to the annual floods that result from the melting of snows in the mountains; nevertheless disastrous floods have several times inflicted severe financial loss on the State by the damage done to agricultural lands, the demolition of bridges, the pollution of waterworks, and the destruction of property in the prosperous cities that are situated in the valley. The greatest of these floods was that of May 23 to June 13, 1903. Severe floods also occurred in 1908.

Between Junction and Kansas City the Kansas receives, in addition to less important tributaries, Big Blue River,[1] Vermilion Creek, Big Soldier Creek, Delaware River, and Big Stranger Creek, from the north, and Mill and Wakarusa creeks from the south.

Mill Creek[2] enters Kansas River at the northeast corner of Wabaunsee County. It rises away to the southwest in the uppermost parts of the Permian and has cut its valley through the various

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[1] For description of Big Blue and Delaware rivers see pp. 249-257.

[2] Kansas Univ. Geol. Survey, vol. 1, p. 206.

limestones to about 100 feet below the Cottonwood limestone. Throughout most of its course the valley is relatively narrow, but is bordered by bluffs similar in every respect to those of Kansas River. At McFarland its south bluff is almost precipitous, rising to a height of 200 feet; but the north bluff, however, is rather a gradual slope than a true bluff.

Wakarusa Creek rises in the eastern part of Wabaunsee County and flows eastward through a farming region across Shawnee and Douglas counties to Eudora, where it joins Kansas River. The course of the creek roughly parallels that of the river from which it is separated by a dissected table-land whose drainage is about equally divided between the river on the north and the creek on the south. The air-line distance across the table-land, from the bed of one stream to that of the other, varies in different places, but is commonly 12 to 15 miles. Wakarusa Creek lies wholly within the Pennsylvanian rocks and it has eroded a valley nearly 50 miles long and 7 to 15 miles wide to a depth nearly equal of that of Kansas River.

The discharge of Kansas River as measured at the gaging stations of the United States Geological Survey at Lawrence and Lecompton is shown in the following tables:

TABLE 123.—*Mean monthly discharge of Kansas River at Lawrence, Kans., for period March 1, 1895, to December 31, 1898, inclusive.*

[Drainage area, 59,800 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 2,687 | 698 | 1,410 |
| February | 11,440 | 692 | 2,948 |
| March | 6,490 | 825 | 2,130 |
| April | 58,000 | 967 | 5,770 |
| May | 34,158 | 787 | 8,870 |
| June | 38,583 | 967 | 10,400 |
| July | 53,308 | 1,255 | 10,500 |
| August | 28,190 | 692 | 6,040 |
| September | 20,050 | 692 | 2,950 |
| October | 7,170 | 787 | 1,260 |
| November | 11,440 | 517 | 1,860 |
| December | 4,035 | 507 | 1,430 |
| The period | 58,000 | 507 | 4,630 |

TABLE 124.—*Mean monthly discharge of Kansas River at Lecompton, Kans., for period between April 1, 1899, and December 31, 1905.*

[Drainage area, 58,600 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 14,170 | 445 | 4,910 |
| February | 21,600 | 275 | 3,010 |
| March | 25,000 | 100 | 8,540 |
| April | 38,350 | 2,250 | 6,930 |
| May | 221,000 | 2,125 | 12,700 |
| June | 205,500 | 2,375 | 18,100 |
| July | 130,000 | 275 | 18,200 |
| August | 58,500 | 275 | 10,300 |
| September | 54,300 | 1,850 | 8,300 |
| October | 42,112 | 445 | 5,920 |
| November | 13,320 | 275 | 5,450 |
| December | 15,900 | 625 | 4,690 |
| The period | 221,000 | 100 | 8,920 |

## QUALITY OF WATER.

### MAIN RIVER.

A sampling station was maintained on Kansas River at Holliday from December 29, 1906, to December 31, 1908. E. W. Johnson was collector. The results of the analyses of the composite samples are presented in Table 125. The series is especially valuable because it covers a period of two years and includes a season from May 5 to September 3, 1908, during which extraordinarily high water prevailed.

The total solids in Kansas River commonly fluctuate with the gage heights, being high when the gage is low, and vice versa, but at Holliday other factors besides the stage of the river determine the amount of total solids in the water. The Kansas at this point carries the waters of the Smoky Hill, the Solomon, the Saline, the Republican, the Big Blue, and the Delaware, rivers which differ greatly in composition. The waters of the first three are highly mineralized, carrying large quantities of calcium, sodium, sulphates, and chlorides; the last three rivers are mineralized in a very much less degree. So the unsatisfactory waters of the Smoky Hill, Solomon, and Saline are improved by dilution with the waters of the Republican, Big Blue, and Delaware. The amount of improvement effected varies from day to day. Sometimes the three eastern streams are low, while the three western flow at moderate stage, and then the percentage of water supplied to the Kansas by the Smoky Hill, Saline, and Solomon is large, and the total solids in the Kansas rise; if, on the other hand, the western streams are low and the eastern high, the total solids drop. At times all of the rivers are low and then the total solids are higher than ever. Sometimes a flood on a single stream affects the total solids in the Kansas decidedly, for not only are the solids in the stream having high stage diluted, but in its swollen condition it furnishes a greater proportion of water than usual to Kansas River and so for the time being becomes an important and even controlling factor in determining the quality of water in the river.

As the total solids vary constantly in the water, so does the percentage of the different metallic and acid radicles. As the calcium, bicarbonates, and sulphates are nearly always high, the temporary and permanent hardness of Kansas River is usually great. When great floods dominate, the hardness becomes much less, but at such times the water is so highly charged with sediment that the improvement worked by the decrease in hardness is more than offset by mud.

An extreme example of the effect of floods on the hardness of the water of the Kansas is afforded by the composite sample of May 25 to June 3, 1908, when the calcium was 49 parts, the magnesium 9.9 parts, the sulphates 32 parts, and the bicarbonates only 12 parts per million.

The chlorides in the Kansas rise and fall from day to day. They are chiefly contributed by Saline, Solomon, and Smoky Hill rivers and vary with the stage of the river and with the percentage of water that each river supplies to the Kansas. The least quantity of chlorides found in any one of the composite samples of Kansas River was 5.9 parts and the greatest 123 parts per million.

This perfectly normal oscillation of chlorides of Kansas River has caused conflicting testimony to be given in court by different water analysts, who were content to express an opinion on the results of a single analysis; and more than one sanitary chemist has erred in attributing the chlorides in the Kansas to sewage pollution. Of course the Kansas is sewage polluted, but most of the chlorides come not from sewage but from salt springs and marshes that originate in the saliferous shales of the Dakota sandstone.

Daily turbidity readings, Table 126, were made with a United States Geological Survey turbidity rod at Lawrence from March 4 to May 1, 1903, and from August 1 to September 2, 1904. The greatest turbidity record during this period was 2,000 and the lowest 50. From December 29, 1906, to May 26, 1907, and from October 9 to November 7, 1907, daily turbidity observations were made at Holliday. (Table 127.) In the 1907 periods the highest recorded turbidity was 5,598 on March 17 and 18; the lowest was 12 on February 5. Sudden jumps in the turbidity of the river are recorded as from 392 on March 9 to 1,200 on March 10, 1907.

TABLE 125.—*Analyses of water from Kansas River near Holliday, Kans.*

[Drainage area, 61,100 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K.) | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$) | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. | Mean gage height (feet).[a] | Mean discharge (cubic feet per second). | Run-off per square mile (cubic feet per second). | Suspended matter (tons per 24 hours). | Dissolved matter (tons per 24 hours). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. Dec. 29 | 1907. Jan. 7 | 47 | 35 | 0.74 | 56 | 1.0 | 92 | 26 | 94 | [b]12 | 341 | 77 | 0.9 | 82 | 564 | 6.2 | 4,340 | 0.071 | 410 | 6,610 |
| 1907. Jan. 8 | Jan. 17 | 62 | 47 | .76 | 25 | 1.0 | 74 | 21 | 77 | [b]3.6 | 319 | 81 | 1.6 | 80 | 495 | 6.3 | 4,510 | .074 | 572 | 6,030 |
| Jan. 19 | Jan. 28 | 298 | 182 | .61 | 61 | 3.0 | 63 | 9.5 | 40 | .0 | 216 | 60 | 3.9 | 28 | 363 | 6.6 | 5,020 | .082 | 2,467 | 4,920 |
| Jan. 29 | Feb. 7 | 18 | 20 | .11 | 25 | 2.0 | 94 | 3.1 | 64 | .0 | 328 | 81 | 2.7 | 60 | 474 | 6.3 | 4,510 | .074 | 244 | 5,770 |
| Feb. 8 | Feb. 13 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 6.6 | 5,020 | .082 | [c]2,500 | ........ |
| Feb. 14 | Feb. 24 | 429 | 343 | .80 | 47 | .40 | 52 | 8.8 | 68 | [b]12 | 171 | 60 | 3.4 | 44 | 375 | 7.0 | 5,700 | .093 | 5,279 | 5,770 |
| Feb. 25 | Mar. 6 | 906 | 587 | .65 | 67 | .8 | 62 | 12 | 68 | .0 | 222 | 47 | 2.3 | 39 | 421 | 7.4 | 6,620 | .108 | 10,492 | 7,520 |
| Mar. 7 | Mar. 18 | 3,425 | 2,313 | .67 | 33 | .40 | 70 | 15 | 37 | .0 | 247 | 60 | 3.0 | 25 | 366 | 8.3 | 8,840 | .145 | 55,207 | 8,740 |
| Mar. 19 | Mar. 30 | 1,672 | 1,219 | .73 | 25 | 2.0 | 82 | 7.9 | 54 | .0 | 278 | 74 | 4.9 | 38 | 415 | 7.1 | 5,930 | .097 | 19,517 | 6,640 |
| Mar. 31 | Apr. 11 | 970 | 630 | .65 | 17 | 6.0 | 87 | 5.4 | 62 | [b]5.0 | 295 | 80 | 2.9 | 54 | 455 | 6.6 | 5,020 | .082 | 8,539 | 6,170 |
| Apr. 12 | Apr. 23 | 80 | 84 | 1.05 | 17 | 1.8 | 82 | 8.7 | 74 | .0 | 335 | 82 | 1.5 | 72 | 505 | 6.4 | 4,680 | .076 | 1,061 | 6,380 |
| Apr. 24 | May 3 | 72 | 82 | 1.14 | 18 | 1.5 | 88 | 12 | 67 | .0 | 315 | 76 | 1.9 | 60 | 459 | 6.3 | 4,510 | .074 | 999 | 5,590 |
| May 4 | May 13 | 117 | 122 | 1.04 | 19 | 1.3 | 78 | 6.4 | 58 | .0 | 280 | 69 | 2.2 | 48 | 407 | 6.2 | 4,340 | .071 | 1,430 | 4,770 |
| May 14 | May 23 | 125 | 151 | 1.21 | 23 | 1.5 | 71 | 2.3 | 76 | .0 | 257 | 81 | 3.3 | 61 | 435 | 6.1 | 4,170 | .068 | 1,700 | 4,900 |
| May 24 | June 6 | 765 | 799 | 1.04 | 24 | 2.0 | 66 | 14 | 57 | .0 | 233 | 57 | 4.0 | 43 | 366 | 6.7 | 5,190 | .085 | 11,196 | 5,130 |
| June 8 | June 19 | 2,940 | 1,976 | .67 | 27 | 3.0 | 55 | 12 | 40 | [b]7.0 | 170 | 43 | 6.8 | 29 | 285 | 8.2 | 8,560 | .140 | 45,669 | 6,590 |
| June 20 | June 29 | 2,093 | 1,336 | .64 | 35 | 7.0 | 56 | 13 | 39 | .0 | 192 | 31 | 6.0 | 18 | 272 | 7.2 | 6,160 | .101 | 22,220 | 4,520 |
| June 30 | July 9 | 2,500 | 1,687 | .67 | 29 | 1.2 | 66 | 14 | 66 | .0 | 217 | 57 | 6.5 | 60 | 371 | 6.7 | 5,190 | .085 | 23,639 | 5,200 |
| July 10 | July 19 | 3,190 | 2,365 | .74 | 39 | 7.0 | 52 | 14 | 50 | [b]11 | 188 | 39 | 4.0 | 29 | 307 | 8.0 | 8,000 | .131 | 51,084 | 6,630 |
| July 20 | July 29 | 2,840 | 2,050 | .72 | 55 | 10 | 44 | 10 | 38 | [b]36 | 68 | 44 | .6 | 17 | 278 | 9.4 | 12,400 | .203 | 68,634 | 9,310 |
| July 30 | Aug. 8 | 1,800 | 1,141 | .63 | 36 | 5.0 | 54 | 18 | 40 | .0 | 185 | 42 | 2.5 | 24 | 277 | 7.5 | 6,850 | .112 | 21,102 | 5,120 |
| Aug. 9 | Aug. 18 | 765 | 644 | .84 | 37 | 2.5 | 65 | 13 | 48 | .0 | 223 | 48 | 2.8 | 37 | 334 | 7.0 | 5,700 | .093 | 9,991 | 5,140 |
| Aug. 19 | Aug. 28 | 400 | 296 | .74 | 34 | .8 | 69 | 17 | 56 | [b]9.0 | 213 | 56 | 2.3 | 45 | 364 | 6.1 | 4,170 | .068 | 3,333 | 4,100 |
| Aug. 29 | Sept. 7 | 80 | 76 | .95 | 32 | .14 | 79 | 21 | 84 | [b]9.0 | 223 | 93 | 1.7 | 79 | 484 | 5.6 | 3,520 | .058 | 722 | 4,600 |
| Sept. 8 | Sept. 17 | 70 | 75 | 1.07 | 35 | .05 | 98 | 19 | 54 | .0 | 327 | 67 | 1.9 | 43 | 450 | 5.3 | 3,160 | .052 | 640 | 3,840 |
| Sept. 18 | Sept. 27 | 55 | 55 | 1.00 | 23 | .04 | 71 | 20 | 35 | .0 | 265 | 52 | Trace. | 19 | 309 | 5.1 | 2,920 | .048 | 434 | 2,440 |
| Sept. 29 | Oct. 8 | 833 | 634 | .76 | 24 | .14 | 79 | 18 | 50 | .0 | 275 | 55 | 2.5 | 42 | 378 | 6.4 | 4,680 | .076 | 8,011 | 4,780 |
| Oct. 9 | Oct. 18 | 1,260 | 694 | .55 | 35 | .6 | 58 | 15 | 76 | .0 | 285 | 56 | 3.3 | 69 | 375 | 6.4 | 4,680 | .076 | 8,769 | 4,740 |
| Oct. 19 | Oct. 31 | 52 | 37 | .71 | 26 | .14 | 85 | 16 | 36 | .0 | 345 | 46 | 1.2 | 27 | 363 | 5.3 | 3,160 | .052 | 316 | 3,100 |
| Nov. 1 | Nov. 10 | 46 | 50 | 1.09 | 19 | .12 | 86 | 14 | 30 | .0 | 260 | 39 | 1.8 | 27 | 289 | 5.3 | 3,160 | .052 | 427 | 2,470 |

[a] Gaging station at Topeka, Kans. [b] Abnormal; computed as $HCO_3$ in the average. [c] Estimated.

TABLE 125.—*Analyses of water from Kansas River near Holliday, Kans.*—Continued.

| Date. | | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. | Mean gage height (feet). | Mean discharge (cubic feet per second). | Run-off per square mile (cubic feet per second). | Suspended matter (tons per 24 hours). | Dissolved matter (tons per 24 hours). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From— | To— | | | | | | | | | | | | | | | | | | | |
| 1907. | 1907. | | | | | | | | | | | | | | | | | | | |
| Nov. 11 | Nov. 20 | 41 | 26 | 0.63 | 22 | 0.12 | 59 | 17 | 39 | 0.0 | 370 | 48 | 0.6 | 13 | 278 | 5.2 | 3,040 | 0.05 | 213 | 2,280 |
| Nov. 21 | Nov. 30 | 37 | 25 | .68 | 21 | .12 | 100 | 13 | 30 | .0 | 320 | 44 | .8 | 11 | 305 | 5.2 | 3,040 | .05 | 205 | 2.500 |
| Dec. 1 | Dec. 7 | 24 | 28 | 1.17 | 19 | .24 | 67 | 16 | 32 | .0 | 335 | 56 | .7 | 19 | 286 | 5.2 | 3,040 | .05 | 230 | 2,350 |
| Dec. 8 | Dec. 17 | 16 | 26 | 1.62 | 20 | .20 | 101 | 19 | 45 | .0 | 342 | 59 | .5 | 41 | 326 | 5.3 | 3,160 | .052 | 213 | 2,780 |
| Dec. 18 | Dec. 27 | 18 | 16 | .89 | 20 | .24 | 61 | 16 | 33 | .0 | 340 | 48 | .6 | 19 | 257 | 6.0 | 4,000 | .065 | 173 | 2,780 |
| | 1908. | | | | | | | | | | | | | | | | | | | |
| Dec. 28 | Jan. 6 | 18 | 21 | 1.17 | 24 | .40 | 77 | 18 | 50 | .0 | 315 | 61 | 1.2 | 32 | 329 | 5.6 | 3,520 | .058 | 200 | 3,130 |
| 1908. | | | | | | | | | | | | | | | | | | | | |
| Jan. 7 | Jan. 16 | 30 | 28 | .93 | 21 | .16 | 96 | 16 | 48 | .0 | 318 | 63 | .8 | 32 | 389 | 5.6 | 3,520 | .058 | 266 | 3,700 |
| Jan. 17 | Jan. 26 | 12 | 40 | 3.33 | 22 | .25 | 96 | 17 | 48 | .0 | 340 | 71 | .5 | 32 | 380 | 5.8 | 3,760 | .062 | 406 | 3,860 |
| Jan. 27 | Feb. 5 | 30 | 13 | .43 | 20 | .10 | 110 | 19 | 71 | .0 | 370 | 80 | 1.4 | 68 | 526 | 5.6 | 3,520 | .058 | 124 | 5,000 |
| Feb. 6 | Feb. 14 | 18 | 20 | 1.11 | 16 | .14 | 102 | 16 | 57 | .0 | 340 | 64 | .6 | 48 | 440 | 6.0 | 4,000 | .065 | 216 | 4,750 |
| Feb. 15 | Feb. 24 | 60 | 51 | .85 | 13 | .13 | 89 | 14 | 41 | .0 | 263 | 62 | 3.6 | 30 | 357 | 6.2 | 4,340 | .071 | 598 | 4,180 |
| Feb. 25 | Mar. 5 | 1,100 | 829 | .75 | 23 | .16 | 79 | 15 | 64 | .0 | 265 | 70 | 3.8 | 67 | 401 | 6.5 | 4,850 | .079 | 10,856 | 5,250 |
| Mar. 6 | Mar. 15 | 240 | 167 | .70 | 24 | .10 | 73 | 15 | 66 | .0 | 260 | 68 | 1.7 | 54 | 402 | 6.3 | 4,510 | .074 | 2,034 | 4,900 |
| Mar. 16 | Mar. 25 | 90 | 40 | .44 | 16 | .10 | 91 | 15 | 44 | .0 | 270 | 61 | .6 | 35 | 364 | 5.9 | 3,880 | .064 | 419 | 3,810 |
| Mar. 26 | Apr. 4 | 70 | 47 | .67 | 14 | .10 | 78 | 14 | 51 | .0 | 300 | 69 | 2.0 | 28 | 342 | 5.7 | 3,640 | .06 | 462 | 3,360 |
| Apr. 5 | Apr. 14 | 90 | 80 | .89 | 24 | .12 | 48 | 15 | 46 | .0 | 295 | 60 | .5 | 34 | 303 | 5.8 | 3,760 | .062 | 812 | 3,080 |
| Apr. 15 | Apr. 24 | 395 | 307 | .78 | 28 | .14 | 62 | 15 | 59 | .0 | 288 | 63 | .8 | 45 | 352 | 6.1 | 4,170 | .068 | 3,457 | 3,960 |
| Apr. 25 | May 4 | 215 | 133 | .62 | 51 | .10 | 93 | 16 | 62 | .0 | 299 | 70 | 2.5 | 52 | 472 | 5.9 | 3,880 | .064 | 1,393 | 4,940 |
| May 5 | May 14 | 4,120 | 3,384 | .82 | 28 | .52 | 55 | 10 | 35 | .0 | 158 | 41 | 8.0 | 18 | 270 | 10.0 | 14,800 | .242 | 135,224 | 1,080 |
| May 15 | May 24 | 2,900 | 2,593 | .89 | 44 | .6 | 56 | 13 | 42 | .0 | 175 | 45 | 8.0 | 22 | 282 | 9.3 | 12,000 | .196 | 83,893 | 9,140 |
| May 25 | June 3 | 3,850 | 3,186 | .83 | 33 | 1.2 | 49 | 9.9 | 32 | a 27 | 12 | 32 | .7 | 9.1 | 250 | 11.6 | 23,600 | .386 | 203,011 | 1,590 |
| June 6 | June 15 | 2,550 | 2,056 | .81 | 23 | .6 | 49 | 8.0 | 29 | .0 | 151 | 28 | 4.5 | 5.9 | 217 | 21.8 | 87,700 | 1.44 | 486,840 | 51,380 |
| June 16 | June 25 | 2,620 | 2,160 | .82 | 33 | 1.2 | 49 | 7.5 | 29 | .0 | 152 | 30 | .4 | 6.5 | 236 | 17.7 | 62,050 | 1.02 | 361,875 | 39,540 |
| June 26 | July 5 | 2,250 | 2,017 | .90 | 26 | .44 | 64 | 13 | 40 | a 11 | 72 | 57 | 3.0 | 22 | 237 | 13.7 | 36,200 | .592 | 197,141 | 23,160 |
| July 6 | July 15 | 2,280 | 2,011 | .88 | 25 | .44 | 58 | 10 | 42 | .0 | 185 | 50 | 4.6 | 24 | 298 | 11.0 | 20,000 | .327 | 108,594 | 16,090 |
| July 16 | July 25 | 2,800 | 2,721 | .97 | 31 | .7 | 51 | 13 | 41 | .0 | 164 | 40 | 4.0 | 23 | 273 | 12.0 | 26,000 | .426 | 191,014 | 19,160 |
| July 26 | Aug. 4 | 2,050 | 1,648 | .80 | 29 | .4 | 54 | 9.8 | 39 | .0 | 227 | 42 | 4.0 | 27 | 288 | 10.2 | 15,840 | .259 | 70,482 | 12,320 |
| Aug. 5 | Aug. 14 | 1,663 | 1,546 | .93 | 27 | .7 | 61 | 13 | 46 | .0 | 206 | 52 | 2.8 | 35 | 321 | 8.8 | 10,240 | .168 | 42,744 | 8,880 |
| Aug. 15 | Aug. 24 | 2,000 | 1,843 | .92 | 32 | .5 | 59 | 11 | 46 | .0 | 184 | 44 | 3.0 | 36 | 310 | 10.3 | 16,360 | .268 | 81,409 | 13,690 |
| Aug. 25 | Sept. 3 | 2,375 | 2,182 | .92 | 31 | .44 | 44 | 6.0 | 45 | a 7.5 | 121 | 34 | 3.2 | 28 | 253 | 10.8 | 18,960 | .310 | 111,701 | 12,950 |
| Sept. 4 | Sept. 13 | 430 | 364 | .85 | 33 | .14 | 78 | 13 | 58 | .0 | 274 | 49 | 1.5 | 53 | 422 | 7.3 | 6,390 | .104 | 6,280 | 7,280 |
| Sept. 14 | Sept. 23 | 111 | 120 | 1.08 | 33 | .14 | 95 | 15 | 84 | .0 | 327 | 119 | 1.0 | 88 | 558 | 6.5 | 4,850 | .079 | 1,571 | 7,310 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 24 | Oct. 3 | 90 | 70 | .78 | 41 | .06 | 94 | 32 | 67 | a2.4 | 329 | ........ | .75 | 107 | 410 | 6.1 | 4,170 | .068 | 788 | 4,620 |
| Oct. 4 | Oct. 13 | 70 | 48 | .68 | 55 | .30 | 96 | 46 | 50 | a11 | 306 | 106 | .75 | 123 | 672 | 5.9 | 3,880 | .064 | 503 | 7,040 |
| Oct. 14 | Oct. 23 | 680 | 1,387 | 2.04 | 23 | .15 | 49 | 46 | 51 | .0 | 149 | 71 | .75 | 22 | 272 | 5.8 | 3,760 | .062 | 14,081 | 2,760 |
| Oct. 24 | Nov. 2 | 140 | 139 | .99 | 45 | .07 | 85 | 21 | ........ | .0 | 303 | 68 | .62 | 45 | 476 | 6.4 | 4,680 | .076 | 1,756 | 6,020 |
| Nov. 3 | Nov. 11 | 150 | 125 | .83 | 41 | .15 | 93 | 20 | 38 | .0 | 312 | 84 | .9 | 48 | 473 | 6.2 | 4,340 | .071 | 1,465 | 5,540 |
| Nov. 12 | Nov. 21 | 1,040 | 505 | .48 | 25 | .07 | 69 | 13 | 44 | .0 | 251 | 90 | 1.4 | 35 | 376 | 5.8 | 3,760 | .062 | 5,127 | 3,820 |
| Nov. 23 | Dec. 2 | 613 | 395 | .64 | 12 | .20 | 70 | 18 | 41 | .0 | 278 | 89 | .87 | 43 | 352 | 6.0 | 4,000 | .065 | 4,266 | 3,800 |
| Dec. 3 | Dec. 13 | 50 | 50 | 1.00 | 23 | .15 | 92 | 24 | 36 | .0 | 266 | 78 | 1.03 | 46 | 428 | 5.9 | 3,880 | .064 | 524 | 4,480 |
| Dec. 14 | Dec. 23 | 50 | 42 | .84 | 12 | .10 | 93 | 27 | 29 | .0 | 295 | 48 | .76 | 38 | 476 | 6.0 | 4,000 | .065 | 454 | 5,140 |
| Dec. 24 | Dec. 31 | 36 | 25 | .69 | 10 | .15 | 92 | 30 | 66 | .0 | 388 | 82 | .94 | 28 | 504 | 5.9 | 3,880 | .064 | 262 | 5,280 |
| Mean........ | | 920 | 736 | .89 | 29 | 1.05 | 73 | 16 | 51 | .0 | 261 | 61 | 2.30 | 41 | 372 | ........ | 8,699 | ........ | 35,100 | 6,989 |
| Per cent of anhydrous residue.... | | ........ | ........ | ........ | 7.2 | .4 | 18.0 | 4.0 | 12.6 | 32.0 | ........ | 15.1 | .6 | 10.1 | ........ | ........ | ........ | ........ | ........ | ........ |

a Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 29, 1906, to November 20, 1907, by F. W. Bushong; November 21, 1907, to September 23, 1908, by Archie J. Weith; September 24 to December 31, 1908, by W. L. Sippy.

TABLE 126.—*Daily turbidity measurements of Kansas River at Lawrence, Kans., and daily gage heights at Lecompton, Kans.*

[James L. Murray and D. F. McFarland, observers.]

| Date. | Turbidity. | Gage heights. |
|---|---|---|
| 1903. | | |
| Mar. 4 | 1,500 | 7.85 |
| Mar. 5 | 1,500 | 7.65 |
| Mar. 6 | 1,500 | 6.80 |
| Mar. 7 | 1,500 | 6.25 |
| Mar. 8 | 1,500 | 5.95 |
| Mar. 9 | 2,000 | 5.55 |
| Mar. 10 | 2,000 | 7.05 |
| Mar. 11 | 1,500 | 8.15 |
| Mar. 12 | 1,500 | 8.90 |
| Mar. 13 | 1,500 | 8.90 |
| Mar. 14 | 1,000 | 9.45 |
| Mar. 15 | 800 | 9.65 |
| Mar. 16 | 800 | 10.00 |
| Mar. 17 | 600 | 9.85 |
| Mar. 18 | 500 | 8.95 |
| Mar. 19 | 400 | 8.70 |
| Mar. 20 | 350 | 8.20 |
| Mar. 21 | 300 | 7.50 |
| Mar. 22 | 250 | 7.40 |
| Mar. 23 | 250 | 7.20 |
| Mar. 24 | 200 | 6.95 |
| Mar. 25 | 180 | 6.65 |
| Mar. 26 | 160 | 6.60 |
| Mar. 27 | 160 | 6.35 |
| Mar. 28 | 150 | 6.05 |
| Mar. 29 | 150 | 5.95 |
| Mar. 30 | 140 | 5.90 |
| Mar. 31 | 130 | 5.85 |
| Mean | 804 | |
| Apr. 1 | 120 | 5.75 |
| Apr. 2 | 120 | 5.70 |
| Apr. 3 | 110 | 5.60 |
| Apr. 4 | 110 | 5.60 |
| Apr. 5 | 110 | 5.50 |
| Apr. 6 | 100 | 5.45 |
| Apr. 7 | 100 | 5.40 |
| Apr. 8 | 100 | 5.10 |
| Apr. 9 | 100 | 4.80 |
| Apr. 10 | 95 | 4.80 |
| Apr. 11 | 95 | 4.70 |
| Apr. 12 | 95 | 4.70 |
| Apr. 13 | 95 | 4.70 |
| Apr. 14 | 90 | 4.65 |
| Apr. 15 | 85 | 4.60 |
| Apr. 16 | 80 | 4.60 |
| Apr. 17 | 75 | 4.55 |
| Apr. 18 | 70 | 4.50 |
| Apr. 19 | 70 | 4.50 |
| Apr. 20 | 70 | 4.50 |
| Apr. 21 | 65 | 4.45 |
| Apr. 22 | 65 | 4.40 |
| Apr. 23 | 60 | 4.40 |
| Apr. 24 | 60 | 4.30 |
| Apr. 25 | 50 | 4.30 |
| Apr. 26 | 55 | 4.30 |
| Mean | 86 | |
| May 1 | 2,000 | 4.00 |
| May 23 | 2,000 | 12.90 |
| Mean | 2,000 | |
| 1904. | | |
| Aug. 1 | 180 | 4.80 |
| Aug. 2 | 275 | 4.55 |
| Aug. 3 | 550 | 4.25 |
| Aug. 4 | 180 | 4.20 |
| Aug. 5 | 130 | 4.15 |
| Aug. 6 | 140 | 4.10 |
| Aug. 7 | 120 | 4.05 |
| Aug. 8 | 110 | 4.00 |
| Aug. 9 | 130 | 4.00 |
| Aug. 10 | 115 | 3.90 |
| Aug. 11 | 108 | 3.85 |
| Aug. 12 | 125 | 3.80 |
| Aug. 13 | 130 | 3.80 |
| Aug. 14 | 135 | 3.80 |
| Aug. 15 | 250 | 3.80 |
| Aug. 16 | 350 | 3.70 |
| Aug. 17 | 350 | 3.70 |
| Aug. 18 | 300 | 3.70 |
| Aug. 19 | 500 | 3.65 |
| Aug. 20 | 400 | 3.60 |
| Aug. 21 | 250 | 3.60 |
| Aug. 22 | 350 | 3.55 |
| Aug. 23 | 300 | 3.50 |
| Aug. 24 | 350 | 3.45 |
| Aug. 25 | 800 | 3.40 |
| Aug. 26 | 750 | 3.40 |
| Aug. 27 | 475 | 3.40 |
| Aug. 28 | 500 | 3.35 |
| Aug. 29 | 500 | 3.30 |
| Aug. 30 | 475 | 3.30 |
| Aug. 31 | 350 | 3.25 |
| Mean | 312 | |
| Sept. 1 | 350 | 3.20 |
| Sept. 2 | 400 | 3.20 |
| Mean | ........ | |

Table 127.—*Turbidity of daily samples of Kansas River at Holliday, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | Oct. | Nov. | Dec. |
| 1 | ........ | 38 | 14 | 1,200 | ........ | 70 | ........ | ........ | 50 | 24 |
| 2 | ........ | 36 | 14 | 1,400 | ........ | 75 | ........ | ........ | 36 | 24 |
| 3 | ........ | 32 | 13 | 1,732 | ........ | 75 | ........ | ........ | 60 | 24 |
| 4 | ........ | 50 | 18 | 1,332 | ........ | 100 | ........ | ........ | 60 | 24 |
| 5 | ........ | 40 | 12 | 520 | ........ | 80 | ........ | ........ | 36 | 18 |
| 6 | ........ | 70 | 20 | 500 | ........ | 105 | ........ | ........ | 40 | 24 |
| 7 | ........ | 52 | 40 | 350 | 115 | 105 | ........ | ........ | 40 | 30 |
| 8 | ........ | 90 | ........ | ........ | 120 | 120 | ........ | ........ | 45 | ........ |
| 9 | ........ | 75 | ........ | 392 | 135 | 120 | ........ | 2,100 | 50 | ........ |
| 10 | ........ | 70 | ........ | 1,200 | 135 | 120 | ........ | 2,250 | 40 | ........ |
| 11 | ........ | 65 | ........ | 2,472 | 105 | 105 | ........ | 2,250 | 45 | ........ |
| 12 | ........ | 90 | ........ | 2,550 | 105 | 135 | ........ | 2,100 | 50 | ........ |
| 13 | ........ | 75 | ........ | ........ | 68 | 180 | ........ | 1,450 | 50 | ........ |
| 14 | ........ | 80 | 473 | 5,355 | 90 | 85 | ........ | 1,000 | 50 | ........ |
| 15 | ........ | 40 | 500 | 5,355 | 75 | 180 | ........ | 675 | 40 | ........ |
| 16 | ........ | 18 | 473 | 5,355 | 75 | 180 | ........ | 350 | 40 | ........ |
| 17 | ........ | 14 | 450 | 5,598 | ........ | 125 | 2,400 | 210 | 50 | ........ |
| 18 | ........ | ........ | 450 | 5,598 | 65 | 115 | 2,499 | 215 | 24 | ........ |
| 19 | ........ | 412 | 440 | 440 | 70 | 115 | ........ | 75 | 24 | ........ |
| 20 | ........ | 370 | 460 | 500 | 65 | 110 | ........ | 80 | 40 | ........ |
| 21 | ........ | 412 | ........ | 500 | 78 | 130 | ........ | 60 | 50 | ........ |
| 22 | ........ | 412 | 418 | 532 | 85 | 105 | ........ | 40 | 45 | ........ |
| 23 | ........ | 440 | 315 | 5,355 | 85 | 100 | ........ | 45 | 36 | ........ |
| 24 | ........ | 406 | 308 | ........ | 75 | 125 | ........ | 60 | 36 | ........ |
| 25 | ........ | 440 | 412 | ........ | 75 | 130 | ........ | ........ | 24 | ........ |
| 26 | ........ | 28 | 500 | ........ | 65 | 112 | ........ | 45 | 30 | ........ |
| 27 | ........ | 20 | 532 | ........ | 75 | ........ | ........ | ........ | 45 | ........ |
| 28 | ........ | 38 | 933 | ........ | 65 | ........ | ........ | 32 | 24 | ........ |
| 29 | 60 | 15 | ........ | ........ | 70 | ........ | 3,650 | 60 | 45 | ........ |
| 30 | 55 | 17 | ........ | ........ | 75 | ........ | ........ | 40 | 30 | ........ |
| 31 | 45 | 20 | ........ | ........ | ........ | ........ | ........ | 30 | ........ | ........ |
| Mean | 53 | 132 | 324 | 2,297 | 86 | 115 | 2,850 | 636 | 41 | 22 |

Note.—March average: 26 to 30, 1,680; March 31 to April 4, 1,800. June average: 1 to 6, 765; 8 to 16, 3,060; 20 to 28, 1,920; June 30 to July 9, 2,500. July average: 10 to 19, 3,190; 20 to 29, 2,840; July 30 to August 8, 1,800. August average: 9 to 18, 765; 19 to 28, 400; August 29 to September 7, 80. September average: 8 to 17, 70; 18 to 27, 55; September 29 to October 8, 833. December average: 8 to 17, 16; 18 to 27, 18. Turbidities over 50 were determined by a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

The coefficient of fineness (Table 125) of the composite samples varies a good deal. Most of the time it is fairly high, indicating that the suspended matter is rather coarse; but in some of the samples the coefficient of fineness is low, showing that the suspended matter is fine.

To summarize: Analyses of the composite samples of the Kansas show that the composition of the water is constantly changing, but that the calcium, bicarbonates, and sulphates are almost always high; hence the temporary and permanent hardness of the water is marked. The river is usually very turbid, though from October 19, 1907, to February 24, 1908, the turbidity of the composite samples was never greater than 60 and was usually considerably less. As a gage was maintained on the Kansas at Topeka by the United States Weather Bureau during the entire period that samples were collected at Holliday, and as discharge measurements have been made by the United States Geological Survey at Lecompton, it has been possible to calculate the approximate mean discharge of the Kansas at Holliday for the period during which the samples were collected and so to figure out the amount of denudation accomplished by the river. It appears that during the two years it carried in suspension an average of 35,100 tons and in solution an average of 7,000 tons per 24 hours.

The variation in the composition of Kansas River water at Topeka at different times is shown by analyses 25–36, Table 103, page 207; among these, analysis 35, Table 103, seems to be a test of an abnormal sample. In the other samples the sulphates are high, the chlorides fluctuate a good deal, and the other constituents do in a less degree.

The quality of water of the Kansas at Argentine at different times is shown by analyses 50 to 56, Table 103, and that of Kansas River at Armourdale and Kansas City, Kans., by analyses 57 and 58, Table 103.

### MINOR TRIBUTARIES.

Between Junction and Manhattan the principal tributary received by the Kansas is Clarks Creek, but no test was made of its water. A little above Manhattan Wild Cat Creek enters. The State Agricultural College discharges its unpurified sewage into the creek, which carries it some distance before emptying it into Republican River. Formerly, the outlet of the sewerage system at its present location discharged directly into Republican River, but the river shifted its channel by cutting off an oxbow bend, and imposed the work of carrying the sewage on the small creek.

A test of a sample taken above the outlet of the sewer of the institution (assay 31, Table 102) shows the water to have decided temporary and permanent hardness.

The water of Vermilion River, assay 37, Table 102, is soft. The quality of the water of Mill Creek is shown by 2 analyses and 1 assay. Analysis 23, Table 103, made in 1902, indicates considerable permanent and high temporary hardness, but analysis 24, Table 103, indicates much greater permanent hardness and less carbonates than shown in the preceding analyses and agrees very well with assay 41, Table 102.

The water of Big Soldier Creek (assay 42, Table 102) has high temporary and low permanent hardness.

Shonganunga Creek, assay 43, Table 102, has low temporary and high permanent hardness. The water of the lake at Lakeview (assay 48, Table 102) appears to be very soft, but its composition is probably changeable. South Fork of Sweezy Creek (assay 46, Table 102) carries soft water, while the water of Sweezy Creek itself (assay 47, Table 102) has considerable permanent hardness.

Martin Creek and Mud Creek (assays 49 and 50, Table 102) are very much alike, having water of low permanent and high temporary hardness.

Tests of the waters of Wakarusa Creek and its tributaries are recorded in analyses 45 and 46, Table 103, and assays 51, 52, 53, and 54, Table 102. The tests indicate that the temporary hardness of these waters is always high and that the permanent hardness varies, sometimes being great enough to be troublesome and at others falling to a point where it is not so.

The results of tests of Big Stranger Creek and its tributary, Nine Mile Creek at Linwood, are given in assays 55, 56, and 57, Table 102, and analysis 47, Table 103, which indicate that the waters of both streams are soft.

Cedar Creek (assay 58, Table 102) carries water having low temporary and high permanent hardness. The water in the railroad pond on Mill Creek at Olathe is shown by assay 59, Table 102, and analysis 48, Table 103, to have very low temporary hardness; the permanent hardness, however, is at times rather high.

A test of the water of Mill Creek at its mouth (assay 60, Table 102) indicates that the temporary hardness is low and the permanent high.

## BIG BLUE RIVER.[1]

### DESCRIPTION.

Big Blue River rises in the northeastern part of Hamilton County, Nebr., near Platte River, and flows northeastward to Ulysses, Nebr., where it turns and flows southward to its junction with Kansas River at Manhattan. Its drainage area, including all tributaries, is 9,490 square miles, of which 7,040 square miles are in Nebraska and 2,450 square miles are in Kansas. At Seward, Nebr., the Big Blue receives from the west, Northwest Branch; at a point south of Camden, Nebr., Beaver Creek enters; and at Dewitt, Nebr., Turkey Creek comes in. Above Beatrice, Nebr., the channels of Big Blue River and its branches lie in Cretaceous rocks; at Beatrice the river enters the Permian, and at Blue Rapids, Kans., the main channel cuts into the Pennsylvanian, in which it continues to its mouth.

Little Blue River, the principal tributary of the Big Blue, heads in the unconsolidated sand and gravels of the Tertiary and flows southeastward. At Belvedere, in Kearney County, Nebr., it enters the Cretaceous, in which it continues, except for a short distance in the Tertiary from Fairbury to Endicott, Nebr., to a point a little south of the Kansas-Nebraska State line in Washington County, Kans., where it crosses into the Permian, in which it flows to its junction with Big Blue River, a short distance above Blue Rapids. The drainage area of Little Blue River in Nebraska is about 13,000 square miles, and the flow of the stream is constant, even in periods

[1] Water-Supply Paper U. S. Geol. Survey No. 216, 1907, p. 36; Kansas Univ. Geol. Survey, vol. 5, p. 35.

of dry weather. Much of the water is derived from springs issuing from the Tertiary and from the Dakota sandstone.

In the wide valley of Platte River nearly all of the coarser materials, especially the basal beds of the alluvium and the coarser portions of the alluvium near the stream, are filled with water, which is obtainable by shallow wells. Although in dry weather Platte River shows very little water at the surface, just below the dry sand and shingle in its bed there is a sheet of water which extends widely under the alluvial flat on either side. These permeable alluvial materials and more or less underlying coarse material contain a large supply of water. As the valley of Platte River is somewhat higher than the adjoining valleys of the branches of Blue, Republican, and Loup rivers, the waters that lie in its bottom flow out laterally through the coarse material underlying the loess and issue as springs or underground seepage in these deeper depressions. In the vicinity of Grand Island the evidence is very clear that the Platte waters pass under the loess-covered divide and emerge in the deep valleys of the headwaters of branches of Big Blue River, which are considerably lower in altitude than the bottom of the Platte Valley. The underflow from Platte River passes southeastward under Adams County through sands and gravels which present everywhere relatively uniform relations. The waters are more or less free to escape into the valley of Little Blue River, which quite deeply trenches the plains region in the southern portion of this county.[1]

In freshets the Little Blue River shifts its channel in sandy bottom lands and has done considerable damage by cutting across valuable farm lands.

The best water power in Kansas is developed at Blue Rapids, where Big Blue River passes over a fall. It is estimated that at low water 1,500 horsepower is generated.

The valleys of the Big and Little Blue Rivers in Kansas are dissected in a plateau of about 1,300 feet in elevation, which is so indented by the drainage as to present a rugged topography. The valley of the Big Blue is one-half to 1 mile in breadth, and 100 feet deep, while that of the Little Blue, though of about the same depth, varies in breadth.

The discharge of Big Blue River, estimated from records kept by the United States Geological Survey, is shown in the following table:

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[1] Water-Supply Paper U. S. Geol. Survey No. 12, 1898, pp. 24-25.

TABLE 128.—*Mean monthly discharge of Big Blue River at Manhattan, Kans., for period from April 14, 1895, to October 31, 1905, inclusive; omitting March and April, 1896, and January and February, 1904.*

[Drainage area, 9,490 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 2,710 | 270 | 744 |
| February | 11,640 | 408 | 1,124 |
| March | 10,830 | 475 | 1,560 |
| April | 32,256 | 408 | 2,000 |
| May | 68,770 | 408 | 4,120 |
| June | 66,170 | 460 | 4,460 |
| July | 43,430 | 210 | 4,050 |
| August | 34,710 | 69 | 2,520 |
| September | 29,990 | 69 | 1,720 |
| October | 20,006 | 124 | 1,170 |
| November | 5,860 | 210 | 908 |
| December | 3,136 | 325 | 778 |
| The period | 68,770 | 69 | 2,100 |

QUALITY OF WATER.

The United States Geological Survey maintained a daily sampling station on Big Blue River at Manhattan from December 19, 1906, to December 19, 1907. Ed. Marksheffel was collector.

A record of the analyses of composite samples of water collected at this station is presented in Table 129. These analyses indicate that Big Blue River carries a calcic alkaline water of moderately high temporary hardness and low permanent hardness. The chlorides are low and vary considerably in amount. The analysis of water from Big Blue River, recorded as No. 21, Table 103, is similar to that of the composite sample of January 18 to 27, Table 129.

Increase in turbidity is generally a sign of a rise in the river; as a rule the total dissolved solids rise when the river falls. The table, however, shows exceptions to this rule, some of which are doubtless due to the fact that an increase in turbidity may indicate a local disturbance of the stream instead of a higher stage.

Daily turbidity determinations, Table 130, show the Big Blue to be more turbid than the Smoky Hill, the Saline, or the Solomon. In the Big Blue a period of low turbidity extended from December 19, 1906, to February 9, 1907, after which the river was decidedly turbid up to March 27, then the turbidity remained low until May 28, when a period of high turbidity set in, which continued until October 20, except for a period of low turbidity from September 19 to 29. Thereafter, except on November 6, November 30, and December 9, the turbidity of the river was low. Of the 352 turbidity readings made, 41 per cent were less than 50, over 47 per cent 100, or greater than 100, and over 11 per cent 1,000 or greater. The records indicate some sudden jumps in turbidity, as from 58 on May 27 to 732 on May

28, and from 600 on July 15 to 11,000 on July 16. The lowest turbidity, 5, was recorded on January 16 and February 5; the highest, 11,000, occurred on July 16. The coefficient of fineness, Table 129 varies considerably but is usually high, except in the three last composites in the table. Thus the coefficient shows that the matter carried in suspension by the stream is usually coarse but that occasionally it is fine enough to give trouble in slow sand filters.

TABLE 129.—*Analyses of water from Big Blue River, at Manhattan, Kans.*

[Drainage area, 9,490 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. Dec. 19 | 1906. Dec. 28 | 24 | 18 | 0.75 | 11 | 1.0 | 87 | 17 | 49 | *a*11 | 326 | 60 | 0.2 | 33 | 422 |
| Dec. 29 | 1907. Jan. 7 | 16 | 16 | 1.00 | 26 | .6 | 72 | 13 | 41 | *a*3.5 | 316 | 55 | 1.6 | 28 | 373 |
| 1907. Jan. 8 | Jan. 17 | 16 | 12 | .75 | 26 | .8 | 82 | 9.1 | 44 | *a*8.6 | 313 | 54 | 2.6 | 7.2 | 386 |
| Jan. 18 | Jan. 27 | 43 | 38 | .88 | 54 | .6 | 77 | 15 | 43 | *a*4.8 | 310 | 61 | 1.9 | 19 | 398 |
| Jan. 28 | Feb. 6 | 17 | 18 | 1.06 | 59 | 1.4 | 87 | 19 | 49 | *a*22 | 324 | 58 | 2 | 23 | 458 |
| Feb. 7 | Feb. 16 | 373 | 298 | .80 | 36 | .22 | 74 | 20 | 79 | .0 | 228 | 138 | 2 | 31 | 471 |
| Feb. 17 | Feb. 26 | 392 | 369 | .94 | 43 | .8 | 44 | 4.6 | 29 | .0 | 169 | 34 | 4 | 8.8 | 262 |
| Feb. 27 | Mar. 8 | 293 | 261 | .89 | 45 | .70 | 62 | 13 | 38 | .0 | 227 | 43 | 3 | 16 | 453 |
| Mar. 9 | Mar. 18 | 718 | 584 | .81 | 36 | .6 | 54 | 15 | 39 | .0 | 204 | 39 | 4.8 | 8.4 | 283 |
| Mar. 19 | Mar. 28 | 176 | 163 | .93 | ..... | 6 | 68 | 4.9 | 43 | .0 | 274 | 40 | 1.5 | 19 | 348 |
| Mar. 29 | Apr. 8 | 46 | 49 | 1.06 | 22 | .9 | 83 | 15 | 40 | *a*7.4 | 318 | 53 | .2 | 21 | 389 |
| Apr. 9 | Apr. 18 | 39 | 31 | .79 | 31 | 2.6 | 86 | 20 | 44 | *a*10 | 340 | 41 | .9 | 26 | 399 |
| Apr. 19 | Apr. 30 | 22 | 22 | 1.00 | 18 | 1.6 | 86 | 17 | 45 | .0 | 337 | 55 | 1.2 | 29 | 395 |
| May 1 | May 10 | 19 | 17 | .89 | 25 | 3.5 | 86 | 3.9 | 47 | *a*8.0 | 312 | 56 | .9 | 26 | 391 |
| May 11 | May 20 | 28 | 37 | 1.32 | 25 | .50 | 86 | 12 | 45 | *a*8.0 | 320 | 55 | .8 | 27 | 398 |
| May 21 | May 30 | 495 | 658 | 1.33 | 26 | 5.5 | 71 | 10 | 48 | .0 | 280 | 50 | 1.7 | 23 | 348 |
| May 31 | June 9 | 1,136 | 917 | .81 | 21 | 4 | 40 | 14 | 27 | .0 | 153 | 27 | 5 | 10 | 158 |
| June 10 | June 19 | 4,180 | 2,783 | .67 | 79 | 6 | 31 | 9.1 | 29 | .0 | 115 | 20 | 1 | 7 | 285 |
| June 20 | June 29 | 740 | 625 | .84 | 37 | 3.5 | 52 | 10 | 41 | .0 | 188 | 29 | 4 | 17 | 254 |
| June 30 | July 9 | 666 | 495 | .74 | 40 | 4 | 49 | 20 | 39 | .0 | 210 | 31 | 7 | 15 | 495 |
| July 10 | July 19 | 1,455 | 1,522 | 1.04 | 19 | .7 | 46 | 13 | 43 | .0 | 175 | 27 | 5.5 | 18 | 256 |
| July 20 | July 29 | 2,156 | 1,671 | .77 | 50 | 40 | 33 | 17 | 30 | .0 | 120 | 18 | 6 | 5 | 227 |
| July 30 | Aug. 8 | 620 | 472 | .76 | 35 | 2 | 55 | 18 | 30 | .0 | 210 | 35 | 3 | 19 | 282 |
| Aug. 9 | Aug. 18 | 900 | 890 | .99 | 30 | 5 | 63 | 11 | 34 | .0 | 185 | 29 | 3 | 10 | 380 |
| Aug. 19 | Sept. 1 | 158 | 118 | .75 | 31 | .8 | 68 | 16 | 44 | .0 | 240 | 36 | 2.5 | 23 | 304 |
| Sept. 2 | Sept. 12 | 160 | 139 | .87 | 32 | .10 | 63 | 16 | 46 | *a*8.0 | 228 | 26 | 2.2 | 25 | 321 |
| Sept. 13 | Sept. 22 | 100 | 148 | 1.48 | 39 | .03 | 80 | 16 | 48 | .0 | 280 | 41 | 1.3 | 28 | 354 |
| Oct. 1 | Oct. 13 | 1,582 | 1,042 | .66 | 35 | .8 | 44 | 10 | 34 | .0 | 165 | 32 | 3.3 | 15 | 234 |
| Oct. 14 | Oct. 23 | 140 | 106 | .76 | 35 | .40 | 60 | 13 | 47 | .0 | 228 | 34 | 2 | 23 | 305 |
| Oct. 24 | Nov. 3 | 57 | 45 | .79 | 40 | .24 | 83 | 21 | 68 | .0 | 270 | 41 | 1 | 31 | 354 |
| Nov. 4 | Nov. 13 | 47 | 39 | .83 | 36 | .20 | 68 | 15 | 47 | .0 | 296 | 43 | .6 | 30 | 361 |
| Nov. 14 | Nov. 23 | 25 | 15 | .60 | 32 | .20 | 78 | 18 | 47 | .0 | 300 | 46 | .5 | 29 | 372 |
| Nov. 24 | Dec. 3 | 24 | 10 | .42 | 33 | .18 | 75 | 21 | 54 | .0 | 305 | 46 | .5 | 29 | 376 |
| Dec. 4 | Dec. 20 | 29 | 18 | .62 | 24 | .10 | 73 | 18 | 61 | .0 | 305 | 46 | .2 | 28 | 360 |
| Mean | | 497 | 401 | .87 | 34 | 3 | 67 | 14 | 44 | .0 | 258 | 44 | 2.3 | 21 | 348 |
| Per cent of anhydrous residue | | ...... | ...... | ...... | 9.5 | 1.2 | 18.8 | 3.9 | 12.3 | 35.5 | ...... | 12.3 | .6 | 5.9 | ..... |

*a* Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 19, 1906, to February 6, 1907, and from March 19 to December 3, 1907, by F. W. Bushong; from February 7 to March 18 and from December 4 to December 20, 1907, by Archie J. Weith.

Table 130.—*Turbidity of daily samples from Big Blue River at Manhattan, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | ...... | 14 | 16 | 125 | 42 | 13 | 2,196 | 1,530 | 580 | 95 | 80 | 60 | 24 |
| 2 | ...... | 27 | 16 | 115 | 105 | 33 | 1,600 | ........ | 900 | 95 | 80 | 45 | 18 |
| 3 | ...... | 19 | 16 | 115 | 46 | 20 | 1,530 | ........ | 666 | 125 | 510 | 45 | 24 |
| 4 | ...... | 11 | 16 | 120 | 26 | 22 | 933 | ........ | 340 | 145 | 4,120 | 36 | 24 |
| 5 | ...... | 11 | 5 | 430 | 26 | 14 | 650 | ........ | 210 | 160 | ...... | 36 | 18 |
| 6 | ...... | 20 | 14 | 732 | 27 | 14 | 600 | ........ | 280 | 170 | 2,725 | 120 | 18 |
| 7 | ...... | 17 | 10 | 632 | 40 | 14 | 400 | ........ | 190 | 215 | 1,950 | 24 | ...... |
| 8 | ...... | 24 | 8 | 562 | 46 | 22 | 485 | 440 | 200 | 230 | 1,175 | 24 | 24 |
| 9 | ...... | 16 | 8 | 425 | 36 | 22 | 765 | ........ | 317 | 165 | 950 | 45 | 160 |
| 10 | ...... | 24 | 440 | 933 | 58 | 18 | 8,415 | 406 | 800 | 200 | 600 | 80 | 16 |
| 11 | ...... | 9 | 440 | 933 | 40 | 18 | 4,840 | 420 | 900 | 150 | 700 | 36 | 24 |
| 12 | ...... | 15 | 600 | 933 | 32 | 90 | 8,415 | 406 | 2,780 | 105 | 580 | 40 | 24 |
| 13 | ...... | 20 | 650 | 933 | 32 | 22 | 3,652 | 400 | 1,000 | 90 | 485 | 30 | 18 |
| 14 | ...... | 16 | 732 | 765 | 38 | 24 | 3,900 | 385 | 732 | 100 | 260 | 40 | ...... |
| 15 | ...... | 16 | 430 | 765 | 50 | 12 | 3,300 | 600 | 933 | 120 | 240 | 18 | 18 |
| 16 | ...... | 5 | 412 | 510 | 45 | 12 | 3,120 | 11,000 | 562 | 125 | 190 | 24 | 32 |
| 17 | ...... | 10 | 613 | 500 | 27 | 24 | 2,220 | 4,530 | 632 | 100 | 120 | 24 | 16 |
| 18 | ...... | 10 | 485 | 485 | 28 | 30 | 2,100 | 3,300 | 355 | 190 | 120 | 24 | 10 |
| 19 | 20 | 12 | 500 | 412 | 20 | 20 | 1,866 | 3,000 | 317 | 90 | 100 | 16 | 15 |
| 20 | 20 | 20 | 564 | 265 | 16 | 26 | 1,000 | 3,000 | 230 | 85 | 120 | 32 | 16 |
| 21 | 20 | 36 | 500 | 200 | ...... | 27 | 833 | 3,000 | ........ | 75 | 80 | 15 | ...... |
| 22 | 22 | 110 | 332 | 150 | 20 | 16 | 933 | 2,195 | 150 | 70 | 90 | 16 | ...... |
| 23 | 20 | 50 | 308 | 150 | 20 | 20 | 1,000 | 2,000 | ........ | 65 | 75 | 36 | ...... |
| 24 | 22 | 60 | 272 | 210 | 38 | 18 | 562 | 1,900 | 110 | 60 | 75 | 32 | ...... |
| 25 | 19 | 55 | 180 | 115 | 28 | 30 | 933 | 1,666 | 95 | 70 | 50 | 32 | ...... |
| 26 | 40 | 45 | 180 | 105 | 22 | 55 | 532 | 1,932 | 110 | 80 | 50 | 36 | ...... |
| 27 | 20 | 27 | 160 | 95 | 17 | 58 | 500 | 1,600 | 72 | 75 | 80 | 18 | ...... |
| 28 | 31 | 30 | 140 | 60 | 18 | 732 | 550 | 2,400 | 90 | 70 | 50 | 18 | ...... |
| 29 | 15 | 20 | ...... | 60 | 22 | 2,000 | 532 | 1,866 | 110 | 65 | 32 | 18 | ...... |
| 30 | 16 | 14 | ...... | 40 | 16 | 2,000 | 966 | 1,530 | 105 | ...... | 40 | 241 | ...... |
| 31 | 14 | 18 | ...... | ...... | ...... | 2,196 | 244 | 1,300 | 100 | ...... | 45 | ...... | ...... |
| Mean | 21 | 25 | 287 | 396 | 34 | 246 | 1,970 | 2,117 | 495 | 117 | 526 | 42 | 28 |

Note.—Average, June 30 to July 9, 666. Turbidities over 50 were determined by a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge. A few were made by Helen Heald and Adelbert Morrison.

The water of Big Blue River above the mouth of the Little Blue, assay 33, Table 102 (p. 205), is rather soft, though the permanent hardness, as indicated by the sulphate content, approaches the point where it becomes troublesome.

The first tributary of Big Blue River in Kansas, of which a test was made, is Spring Creek at Marysville. This stream lies wholly within the Permian, but assay 32, Table 102, shows its water to be soft.

Tests of the water of Mill Creek at Washington are given in assay 34, Table 102, and analysis 20, Table 103 (p. 206), which show low temporary and marked permanent hardness.

Little Blue River carries soft water at both Hanover and at Blue Rapids (assays 35 and 36, Table 102), but at the lower point the permanent hardness is considerably greater than at the upper. The results of tests of Black Vermilion River and its tributary, Vermilion Creek, are given in assays 37 and 38, Table 102. The creek and river appear to be very similar in composition, though the bicarbonates in the creek water are higher than in the river. The water of Fancy

Creek (assay 39, Table 102), also shows similarity in composition to that of Vermilion Creek and Black Vermilion River, although Fancy Creek and its tributaries, through practically their entire courses, flow in the Permian rocks, and might be expected to be heavily mineralized from the shales of that formation, whereas Black Vermilion River and its tributaries lie wholly within the Pennsylvanian series. The streams flowing in the eastern part of the Permian area of Kansas, however, are not so heavily mineralized as those in the northern, middle, and southern area, where gypsum deposits outcrop or are very near the surface. It is worthy of note that though both Fancy Creek and Black Vermilion River flow close to the large gypsum deposits of the Blue Rapids gypsum area, neither stream derives any considerable drainage from the gypsum deposits.

Although Big Blue River and its chief tributary, Little Blue River, flow in the Cretaceous through a considerable portion of their courses in Nebraska, they appear not to receive the overflow of salt springs and marshes originating in the Dakota, as the Saline, Solomon, and Republican Rivers do in Kansas. It is stated,[1] however, that along Little Blue Valley and at places near Rose Water Creek near Thayer County, Nebr., the water obtained from wells in the Dakota sandstone is somewhat salty, and that at Gladstone in Jefferson County, and at a number of points between Powell and Steele, wells in the Dakota obtain saline water; it is stated also [2] that there is a general seepage into Big Sandy Creek and Little Blue River from the Dakota sandstone and Pleistocene sands in the northwestern part of the county.

## DELAWARE RIVER.[3]

### DESCRIPTION.

Delaware River, known to the pioneers as Grasshopper River, is formed in the Kickapoo Indian Reservation at the southwestern part of Brown County, Kans., by the confluence of Cedar and Craig creeks and flows southward to Perry, where it discharges into Kansas River. The river, which is 80 miles long, has cut its channel deep into the Pennsylvanian, forming remarkably precipitous bluffs, but it has not yet reached base level for, at several places in its course are falls caused by resistant limestone strata. Its total drainage area is 1,200 square miles.

### QUALITY OF WATER.

The United States Geological Survey maintained a daily sampling station on Delaware River at Perry, Kans., from January 4, 1907, to June 30, 1907, and at Valley Falls, Kans., from June 12, 1907,

[1] Condra, G. E., Geology and water resources of the Republican River valley and adjacent areas, Nebraska: Water-Supply Paper U. S. Geol. Survey No. 216, 1907, pp. 56-57.

[2] Loc. cit.

[3] Kansas Univ. Geol. Survey, vol. 1, p. 206.

to January 4, 1908. Samples were collected at Perry by C. G. Hart, and at Valley Falls by George Harmon.

A record of the analyses of composites of the samples collected from this river is presented in Table 131, and the results of tests at Valley Falls and Perry also appear in analyses 40–42, Table 103. The analyses of the composites (Table 131) show that the bicarbonates predominate over the sulphates and fluctuate much more than the latter do. At times the water has high temporary hardness and at other times low; the permanent hardness is usually low, but is sometimes great enough to be troublesome. Occasionally, when the river is in flood and is very turbid, both the temporary and permanent hardness are low. The chlorides are low and like the other constituents fluctuate. So far as can be judged from turbidity readings the total dissolved solids as a rule rise and fall with the stage of the river.

Measurements of the daily turbidity of Delaware River are recorded in Table 132, but the record is far from complete. Two hundred and forty turbidity readings were made, nearly 23 per cent of which were less than 50 and over 42 per cent were 100 or greater. The lowest observed turbidity, 2, was recorded on January 17, and the highest, 4,998, on March 18. The record shows several sudden rises in turbidity, as from 12 on January 18 to 4,000 on January 19, and from 60 on March 10 to 4,200 on March 11. The coefficient of fineness of the composite samples (Table 131) varies widely, being very high for some of the samples and low for others.

TABLE 131.—*Analyses of water from Delaware River at Perry, Kans., and Valley Falls, Kans.*[a]

[Drainage area at Perry, 1,200 (estimated) square miles; at Valley Falls, 951 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca.) | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1907. | 1907. | | | | | | | | | | | | | | |
| Jan. 4 | Jan. 13 | 6 | 6.8 | 0.13 | 13 | 0.6 | 99 | 22 | 35 | 0.0 | 392 | 62 | 0.6 | 21 | 408 |
| Jan. 14 | Jan. 23 | 1,140 | 1,186 | 1.04 | 34 | 4.0 | 57 | 5.8 | 32 | .0 | 242 | 43 | 6.0 | 11 | 280 |
| Jan. 24 | Feb. 2 | 268 | 225 | .84 | 43 | 4.8 | 58 | 6.0 | 29 | .0 | 227 | 36 | 3.3 | 6.0 | 288 |
| Feb. 3 | Feb. 12 | 390 | 914 | 2.34 | 33 | 4.0 | 62 | 8.4 | 32 | .0 | 256 | 22 | .2 | 12 | 500 |
| Feb. 13 | Feb. 22 | 570 | 350 | .61 | 29 | .6 | 48 | 8.4 | 27 | .0 | 168 | 33 | 6.6 | 6.0 | 240 |
| Feb. 23 | Mar. 4 | 498 | 64 | .73 | 40 | .24 | 74 | 14 | 38 | .0 | 261 | 39 | 4.2 | 6.9 | 329 |
| Mar. 5 | Mar. 14 | 1,338 | 968 | .72 | 26 | .50 | 60 | 11 | 41 | .0 | 227 | 41 | 4.9 | 7.6 | 309 |
| Mar. 15 | Mar. 24 | 1,044 | 679 | .65 | 17 | 1.8 | 76 | 17 | 30 | .0 | 280 | 41 | 3.6 | 8.8 | 306 |
| Mar. 25 | Apr. 5 | 410 | 715 | 1.74 | 14 | 3.5 | 89 | 17 | 27 | .0 | 371 | 43 | 3.3 | 8.4 | 368 |
| Apr. 6 | Apr. 16 | 111 | 151 | 1.36 | 11 | 2.8 | 85 | ..... | 29 | .0 | 380 | 50 | 3.5 | 14 | 376 |
| Apr. 17 | Apr. 29 | 60 | 69 | 1.15 | 4.6 | 1.0 | 83 | 20 | 33 | .0 | 356 | 48 | 1.8 | 14 | 368 |
| Apr. 30 | May 11 | 47 | 50 | 1.06 | 7.6 | 3.6 | 77 | 16 | 30 | .0 | 350 | 46 | 1.6 | 14 | 325 |
| May 12 | May 22 | 78 | 82 | 1.05 | 11 | 1.2 | 74 | 15 | 35 | .0 | 365 | 49 | 2.1 | 13 | 334 |
| May 24 | June 7 | 90 | 99 | 1.10 | 10 | 1.2 | 93 | 24 | 35 | .0 | 357 | 48 | 2.5 | 48 | 375 |
| June 23 | June 28 | 5,125 | 3,419 | .67 | ..... | ..... | ..... | ..... | ..... | .0 | 140 | ..... | 7.5 | 6 | .... |
| June 12 | June 22 | 1,950 | 1,031 | .53 | 34 | 9.0 | 54 | 18 | 36 | .0 | 195 | 35 | 10 | 10 | 271 |
| June 22 | July 12 | 3,400 | 2,354 | .69 | 69 | 40 | 42 | 20 | 28 | .0 | 157 | 24 | 7.5 | 6 | 272 |
| July 13 | July 23 | 560 | 611 | 1.09 | 22 | 1.5 | 83 | 19 | 37 | [b] 5.0 | 278 | 37 | 6.0 | 11 | 334 |
| July 24 | Aug. 4 | 425 | 365 | .86 | 25 | 6.0 | 68 | 22 | 33 | .0 | 270 | 27 | 4.5 | 12 | 286 |
| Aug. 5 | Aug. 15 | 317 | 200 | .63 | 20 | 1.5 | 73 | 17 | 31 | .0 | 255 | 34 | 3.0 | 10 | 282 |
| Aug. 17 | Aug. 27 | 317 | 225 | .71 | 17 | .09 | 68 | 18 | 33 | .0 | 257 | 29 | 3.0 | 13 | 283 |
| Aug. 28 | Sept. 6 | 200 | 167 | .84 | 24 | .44 | 82 | 19 | 32 | .0 | 232 | 25 | 3.0 | 13 | 298 |
| Sept. 7 | Sept. 17 | 317 | 254 | .80 | 20 | .12 | 50 | 15 | 30 | .0 | 195 | 31 | 3.3 | 9.3 | 253 |
| Sept. 18 | Sept. 28 | 115 | 118 | 1.03 | 21 | .06 | 44 | 17 | 37 | [b] 7.0 | 170 | 46 | .3 | 11 | 198 |
| Oct. 13 | Oct. 23 | 63 | 48 | .76 | 13 | .30 | 73 | 19 | 22 | [b] 9.0 | 250 | 68 | 1.7 | 17 | 337 |
| Oct. 24 | Nov. 22 | 42 | 44 | 1.05 | 16 | .14 | 84 | 19 | 43 | .0 | 330 | 52 | 1.2 | 20 | 377 |
| Nov. 23 | Nov. 29 | 23 | 13 | .57 | 13 | .16 | 67 | 20 | 39 | .0 | 315 | 62 | .8 | 18 | 322 |
| Mean | | 700 | 545 | .95 | 23 | 3.4 | 70 | 16 | 33 | .0 | 270 | 41 | 3.6 | 13 | 320 |
| Per cent of anhydrous residue | | ...... | ...... | ...... | 6.8 | 1.4 | 20.8 | 4.7 | 9.8 | 39.4 | ...... | 12.2 | 1.1 | 3.8 | .... |

[a] Valley Falls, Kans., from June 12 to November 29, 1907.
[b] Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from January 4 to February 12 and from March 15 to October 23, 1907, by F. W. Bushong; from February 13 to March 14 and from October 24 to November 29, 1907, by Archie J. Weith.

TABLE 132.—*Turbidity of daily samples from Delaware River at Perry, Kans., from January 4 to May 31, 1907, and at Valley Falls, Kans., from June 1 to November 29, 1907.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ........ | 55 | 613 | 220 | 32 | 125 | ........ | ........ | ...... | ...... | ...... |
| 2 | ........ | 27 | 700 | 115 | ...... | 100 | ........ | ........ | ...... | ...... | ...... |
| 3 | ........ | 105 | 1,530 | 75 | 45 | ........ | ........ | ........ | 260 | ...... | ...... |
| 4 | 7 | 160 | 1,866 | 75 | 70 | 70 | ........ | ........ | 80 | ...... | ...... |
| 5 | 3 | 110 | 920 | 350 | 65 | 120 | ........ | 305 | 75 | ...... | ...... |
| 6 | 3 | 18 | 600 | 550 | 40 | 140 | ........ | 275 | 70 | ...... | ...... |
| 7 | 3 | 20 | 650 | 48 | 40 | 60 | ........ | 1,530 | ...... | ...... | ...... |
| 8 | 12 | 308 | 160 | 27 | ...... | ........ | ........ | 180 | ...... | ...... | ...... |
| 9 | 15 | 80 | 210 | 85 | 24 | ........ | ........ | 200 | ...... | ...... | ...... |
| 10 | 3 | 90 | 60 | 75 | 65 | ........ | ........ | 70 | ...... | ...... | ...... |
| 11 | 3 | 1,560 | 4,200 | ...... | 62 | ........ | ........ | 90 | ...... | ...... | ...... |
| 12 | 2 | 1,750 | 4,200 | 70 | 95 | ........ | 47 | 50 | ...... | ...... | ...... |
| 13 | 6 | 933 | 473 | 65 | 55 | ........ | 26 | 65 | ...... | 80 | ...... |
| 14 | 5 | 1,160 | 1,866 | 65 | 55 | ........ | 24 | 200 | ...... | 80 | ...... |
| 15 | 8 | 933 | 1,932 | 58 | 60 | ........ | 4,590 | 200 | ...... | 60 | ...... |
| 16 | 20 | 765 | 1,866 | 65 | 55 | ........ | 450 | ........ | ...... | ...... | ...... |
| 17 | 2 | 550 | 500 | 50 | 115 | ........ | ........ | 230 | ...... | 60 | ...... |
| 18 | 12 | 245 | 4,998 | 55 | 60 | ........ | 160 | 155 | 50 | 60 | ...... |
| 19 | 4,000 | 406 | 520 | 45 | 125 | ........ | 100 | 180 | 165 | 50 | 12 |
| 20 | 3,600 | 365 | 190 | ...... | 80 | ........ | 85 | 95 | 90 | 50 | 45 |
| 21 | 1,860 | 293 | 170 | 43 | ...... | ........ | 60 | 95 | 120 | 70 | 40 |
| 22 | 1,335 | 36 | 105 | 70 | 82 | 3,200 | 60 | 70 | 110 | 45 | 36 |
| 23 | 550 | 45 | 80 | ...... | ...... | 6,600 | 28 | 45 | 255 | 70 | 32 |
| 24 | 332 | 70 | 80 | 140 | 85 | 7,000 | 38 | 45 | 100 | 80 | 45 |
| 25 | 277 | 65 | 90 | ...... | 82 | 5,000 | 27 | 55 | 120 | 60 | 16 |
| 26 | 232 | 21 | ........ | 60 | 110 | 765 | 70 | 2,600 | 100 | 50 | 24 |
| 27 | 473 | 35 | 100 | 30 | 120 | 765 | 36 | 150 | 80 | 60 | 18 |
| 28 | 65 | 38 | 210 | 40 | 100 | 3,480 | 115 | 105 | 80 | 45 | 15 |
| 29 | 1,100 | ........ | 2,910 | 65 | 60 | 4,000 | 295 | 100 | ...... | 24 | 15 |
| 30 | 50 | ........ | ........ | 30 | 60 | 3,200 | 2,160 | 600 | ...... | 12 | ...... |
| 31 | 65 | ........ | 50 | ...... | 80 | ........ | ........ | 562 | ...... | ...... | ...... |
| Mean | 502 | 366 | 1,098 | 99 | 71 | 2,308 | 465 | 317 | 130 | 56 | 27 |

NOTE.—Averages, June 12 to 17, 95; June 12 to 22, 1,950; July 24 to August 4, 425; September 7 to 17, 317. Turbidities over 50 were determined by a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

At Muscotah (analysis 38, Table 103, p. 207) Delaware River is high in both sulphates and carbonates. Little Delaware River at Horton carries water having marked permanent and low temporary hardness (assay 44, Table 102, p. 205). Tests of the water of Elk Creek (analysis 39, Table 103, and assay 45, Table 102) indicate a large amount of carbonates and the analysis shows also high sulphates, although the assay does not.

## Osage River Basin.

### DESCRIPTION.

Osage River, called locally in Kansas Marais des Cygnes River, rises in the prairies of eastern Kansas about 30 miles southwest of Topeka and flows southeastward to its junction with the Missouri at Osage, Mo. The entire length of the stream measured along the general trend of the valley, the minor bends being neglected, is about 280 miles, but its actual length is probably at least 500 miles, and the total area of the basin is about 15,300 square miles,[1] of which about 4,300 are in Kansas.

[1] Water-Supply Paper U. S. Geol. Survey No. 172, 1906, p. 264.

The stream has no mountain tributaries but depends for its water supply entirely on precipitation within its basin, which ranges from 35 to 40 inches each year. The stream normally has a gentle current, flowing in a fairly deep channel that changes little from year to year. High water resulting from heavy rainfall is frequent and extensive floods occasionally occur.

The river falls from an elevation of about 1,225 feet above sea level at its source to 755 feet near Ottawa, Kans., in a distance of 50 miles, but for 25 miles above and below Ottawa the fall is not more than 1½ feet to the mile.

The principal tributary of the Osage in Kansas is Pottawatomie Creek, which joins the main stream from the south just below Osawatomie. Marmaton River, which with its tributaries drains all of Bourbon County, Kans., unites with the Osage after it has passed into Missouri.

The channels of the Osage and its tributaries in Kansas lie wholly within the limestones, sandstones, and shales of the Pennsylvanian. The limestones are hard and resist erosion, thus protecting the underlying shales, which are soft and easily disintegrated. The streams have cut through the limestones deep into the shales.

The bluffs are steep, and their height along the river is determined by the westward dip of the limestone beds, which outcrop in succession from east to west. These beds are highest at their eastern ends, which are sharply elevated above the surrounding country, and the bluffs diminish westward at a rate equal to the dip until one bed passes beneath the high eastern end of another, when the bluffs suddenly increase in height, to become low again as they follow the dip of the new system to the west. Thus at Lacygne and Boicourt the bluffs are nearly 200 feet high; while at Osawatomie they are scarcely 100 feet high; at Ottawa the bluffs are little more than 50 feet high, but a few miles to the west, where the Oread limestone outcrops, the bluffs rise to a height of 200 feet.

The valley of Osage River varies from 2 to 4 miles in width and the stream meanders widely within it. The tributaries have cut their channels to a depth equal to that of the Osage itself. The position of Osage River was perhaps determined by the huge syncline in the limestones in the eastern part of the State, for at Boicourt the river has cut through the trough of this fold and it seems reasonable to suppose that this feature formed a natural valley in which the river developed. A feature of the valley of Osage River is the circular mounds, which stand out entirely isolated in the broad valley. They owe their existence to protective caps of limstones.

The topography of the valley of Pottawatomie Creek is peculiar in that from Lane to Osawatomie the valley seems to rise to the east. This peculiarity is explained by the fact that all of this part of the valley is covered by the Iola limestone, so that the higher "Garnett" limestone, on the surface of which the creek rises, was worn through before the Iola limestone was reached. When that resistant formation was encountered vertical corrosion was retarded and lateral erosion became the dominant process, so that the widening of the valley was far advanced before the Iola limestone was cut through. Hence it has come about that the valley proper between Lane and Ottawa lies above the Iola limestone and is 4 or 5 miles wide. The creek has now cut through the Iola limestone and begun a second widening, which has already reached a mile or more in the vicinity of Osawatomie.

## QUALITY OF WATER.

### OSAGE RIVER.

Through the courtesy of C. R. Gray, of the St. Louis and San Francisco Railway, the United States Geological Survey maintained a daily sampling station on Osage River at Boicourt for a period of one year. Samples were collected by J. W. L. Gray. The results of the analyses of the composites of these samples are presented in Table 133. Other tests of the Osage and its tributaries are recorded in Tables 136 and 137.

A cursory inspection of Tables 136 and 137 shows that every stream in the Osage basin in Kansas carries carbonate or bicarbonate waters, except a pond on Salt Creek at Osage (analysis 5, Table 137), a stream from old mines, Scranton (assay 25, Table 136), and Cox Creek, Arcadia (assay 82, Table 136), which carry sulphate waters. Although the bicarbonates numerically are higher than the sulphates in the waters of Salt Creek, Osage (assay 13, Table 136), and Buck Creek, Fort Scott (assay 70, Table 136), these waters should be regarded as sulphate waters, for the chemical ratio[1] of sulphates to bicarbonates is greater than that of bicarbonates to sulphates. Closer scrutiny of Table 136 shows that Osage River above Peoria and its tributaries above Ottawa, including Kenoma Creek (assay 36, Table 136), are high in sulphates, although the main stream and its tributaries below the points mentioned and eastward to the State line are low in sulphates. Erasmus Haworth points out (by letter) that in that part of the Osage basin that lies above Ottawa many of the streams have not yet reached base level, and are therefore cutting down their channels. This means that they are constantly coming in contact with new shales. As the shales contain comparatively large quantities of pyrite, salt, and gypsum, these tributaries of the Osage contribute large quantities of sulphates to the main stream. To the east and southeast the river and its tributaries have cut to base level and have built up

[1] See classification of waters, pp. 20-21.

their flood plains, so that their water channels are no longer in immediate contact with the shales. As the rains are generally as heavy eastward as near the source of the river, the aggregate quantity of water in the streams is much greater and the sulphate solutions are correspondingly diluted. These facts, Haworth states, accord with the observation he has made, that in the area under discussion wells sunk through soil and clay, or alluvium, produce good water, but those that reach the shale are rich in iron and sulphates, because such wells bring the oxygen of the air in contact with the pyrite and oxidize it.

The reasons enumerated by Haworth as sufficient to account for the sulphates in the tributary streams at the head of Osage River are supplemented by the fact that many of the streams are contaminated by coal-mine drainage.

In general, Tables 136 and 137 show that above Ottawa the water of Osage River and its tributaries has moderate temporary and great permanent hardness; below Ottawa it has moderate temporary and low permanent hardness, except tributaries at Fort Scott and eastward to the Kansas-Missouri State line which have high permanent hardness. As a rule the streams of the Osage River Basin are low in chlorides.

The analyses of the composites of the Osage at Boicourt (Table 133) show a calcic alkaline water which at times contains sufficient calcium, magnesium, and sulphates to give it high permanent hardness. The temporary hardness of the water, according to the analyses in Table 133, is never very high and is sometimes low. The chlorides are also low, and the total dissolved solids in few of the samples rise to 300 parts per million.

Two good series of daily turbidity readings on the water of the Osage are available. The results of the first series are recorded in Table 134; the observations were made with a United States Geological Survey turbidity rod at Ottawa from August, 1904, to July, 1905. In this table, too, are recorded observations made with the rod at Lacygne during the month of June, 1904. The highest turbidity recorded during the period from August, 1904, to July, 1905, was 3,000 on March 25, and several times during July, 1905; the lowest turbidity, 17, was recorded on September 29, 1904. From September 6, 1904, to February 22, 1905, the turbidity was always less than 100, and during most of the time was less than 50. During the month of May and from June 19 to July 13, 1905, the river was turbid most of the time. All of the turbidities recorded at Lacygne are high, especially the reading of 5,700 on June 21. The turbidity readings recorded in Table 135 were made on the daily samples at Boicourt, and cover the period from December, 1906, to November, 1907. Three hundred and forty-six readings were made, of which about 16 per cent were less than 50, nearly 47 per cent 100 or more, and a little over 10 per cent were over 1,000. In the 1906–7 period the river was generally more turbid than it was from August, 1904, to July, 1905. The highest turbidity in Table 135 is 3,792, on June 9 and 10, 1907; the lowest turbidity occurred on February 5. From December 6, 1906, to January 16, 1907, all the readings, with the exception of one, are less than 100; as also from April 8 to 29, 1907, and, with the exception of two readings, from September 7 to November 20, 1907. From April 30 to July 12, 1907, and from July 29, to September 5, 1907, the turbidity readings were high. The coefficient of fineness, Table 133, varies considerably, but much of the time it is rather low, showing that the suspended matter is in a somewhat finely divided condition.

TABLE 133.—*Analyses of water from Osage River, at Boicourt, Kans.*

[Drainage area, 2,700 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Nov. 29 | Dec. 8 | 220 | 169 | 0.77 | 22.0 | [a]2.4 | 68 | 6.0 | 41 | 0.0 | 232 | 43 | 3.7 | 10 | 293 |
| Dec. 9 | Dec. 18 | 70 | 51 | .73 | ..... | 3.0 | 58 | 8.7 | 34 | .0 | 202 | 46 | 3.6 | 9.0 | 269 |
| Dec. 19 | Dec. 28 | 44 | 27 | .61 | 19 | 1.6 | 70 | 18 | 29 | .0 | 236 | 51 | 4.0 | 8.8 | 276 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 30 | Jan. 8 | 83 | 57 | .69 | 19 | 1.4 | 75 | 4.8 | 33 | .0 | 260 | 43 | 4.8 | 12 | 295 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 9 | Jan. 18 | 64 | 54 | .84 | 21 | .30 | 41 | 1.9 | 25 | [b]12 | 241 | 35 | 4.4 | 10 | 293 |
| Jan. 19 | Jan. 28 | 1,016 | 808 | .80 | 39 | 4.0 | 43 | 7.2 | 22 | .0 | 138 | 37 | 8.0 | 3.9 | 220 |
| Jan. 29 | Feb. 7 | 55 | 51 | .93 | 45 | 1.8 | 87 | 6.8 | 27 | [b]11 | 278 | 40 | 5.7 | 8.3 | 352 |
| Feb. 8 | Feb. 17 | 247 | 176 | .71 | 27 | .24 | 77 | 12 | 36 | .0 | 249 | 49 | 3.6 | 6.9 | 310 |
| Feb. 19 | Feb. 28 | 67 | 41 | .61 | 42 | .30 | 105 | 5.6 | 31 | .0 | 248 | 46 | 6.2 | 8.4 | 327 |
| Mar. 1 | Mar. 11 | 1,007 | 686 | .68 | 29 | .50 | 69 | 8.7 | 26 | .0 | 204 | 50 | 4.0 | 6.9 | 298 |
| Mar. 12 | Mar. 21 | 810 | 613 | .76 | 19 | 3.4 | 68 | 2.6 | 20 | .0 | 192 | 44 | 4.8 | 4.1 | 259 |
| Mar. 22 | Mar. 31 | 516 | 378 | .73 | 20 | 5 | 70 | 3.1 | 24 | [b]3.1 | 260 | 43 | 2.2 | 8.2 | 298 |
| Apr. 1 | Apr. 10 | 297 | 212 | .71 | 12 | 1.5 | 73 | 3.7 | 20 | .0 | 240 | 39 | 2.3 | 7.6 | 275 |
| Apr. 11 | Apr. 21 | 45 | 45 | 1.00 | 7.2 | 1.0 | 84 | 2.0 | 22 | .0 | 275 | 44 | 1.2 | 11 | 292 |
| Apr. 22 | May 2 | 286 | 291 | 1.02 | 9.0 | 2.0 | 74 | 11 | 26 | .0 | 247 | 39 | 1.7 | 12 | 277 |
| May 3 | May 13 | 473 | 410 | .87 | 19 | 5 | 65 | 2.0 | 23 | .0 | 195 | 40 | 6.0 | 6.0 | 249 |
| May 14 | May 23 | 700 | 692 | .99 | 17 | 1.2 | 73 | 11 | 20 | .0 | 232 | 42 | 6.5 | 6.0 | 277 |
| May 24 | June 4 | 100 | 109 | 1.09 | 21 | .8 | 90 | 3.6 | 18 | .0 | 273 | 42 | 4.0 | 9.0 | 303 |
| June 5 | June 14 | 1,850 | 1,479 | .80 | 20 | 6 | 57 | 9.9 | 22 | .0 | 185 | 33 | 6.0 | 7.0 | 239 |
| June 15 | June 24 | 1,140 | 846 | .74 | 23 | 5 | 57 | 19 | 28 | .0 | 187 | 31 | 7.0 | 4.0 | 232 |
| June 25 | July 10 | 1,200 | 1,094 | .91 | ..... | 3.5 | 48 | 13 | 21 | .0 | 170 | 31 | 6.0 | 5.0 | 180 |
| July 11 | July 21 | 84 | 82 | .98 | 32 | 2 | 78 | 16 | 35 | [b]10 | 238 | 33 | 3.5 | 12.0 | 310 |
| July 22 | Aug. 1 | 139 | 231 | 1.66 | 23 | 2 | 64 | 8.8 | 23 | [b]9.0 | 125 | 32 | .6 | 4.0 | 228 |
| Aug. 2 | Aug. 11 | 210 | 135 | .64 | 58 | 12 | 32 | 12 | 25 | [b]17 | 152 | 21 | 3.8 | 5 | 234 |
| Aug. 12 | Aug. 21 | 282 | 223 | .79 | 36 | 3.6 | 65 | 15 | 39 | .0 | 188 | 24 | 3.2 | 11 | 245 |
| Aug. 22 | Sept. 3 | 284 | 205 | .72 | 23 | .7 | 47 | 11 | 19 | .0 | 145 | 20 | 3.0 | 5 | 185 |
| Sept. 4 | Sept. 17 | 80 | 73 | .91 | 45 | .22 | 49 | 11 | 27 | .0 | 190 | 19 | 1.9 | 8 | 237 |
| Sept. 18 | Sept. 29 | 75 | 52 | .69 | 19 | .20 | 65 | 12 | 27 | .0 | 198 | 22 | .6 | 10 | 215 |
| Sept. 30 | Oct. 14 | 80 | 51 | .64 | 15 | .16 | 58 | 12 | 26 | [b]5.0 | 205 | 25 | .3 | 13 | 233 |
| Oct. 15 | Oct. 24 | 55 | 31 | .56 | 15 | .14 | 72 | 35 | 34 | .0 | 245 | 27 | .5 | 22 | 279 |
| Oct. 25 | Nov. 4 | 42 | 34 | .81 | 17 | .15 | 70 | 14 | 22 | .0 | 248 | 32 | 1.2 | 26 | 293 |
| Nov. 5 | Nov. 17 | 36 | 18 | .50 | 12 | .36 | 74 | 11 | 42 | .0 | 280 | 34 | .9 | 43 | 333 |
| Nov. 18 | Nov. 30 | 85 | 59 | .69 | 13 | .12 | 83 | 13 | 43 | .0 | 250 | 32 | .8 | 26 | 290 |
| Mean | | 356 | 287 | .80 | 24 | 2.2 | 67 | 12 | 28 | .0 | 222 | 36 | 3.5 | 10 | 270 |
| Per cent of anhydrous residue | | ...... | ...... | ...... | 8.2 | 1.1 | 22.9 | 4.1 | 9.6 | 37.2 | ...... | 12.3 | 1.2 | 3.4 | ..... |

[a] Al=1.8.

[b] Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from November 29, 1906, to February 7, 1907, and from March 12 to November 17, 1907, by F. W. Bushong; from February 8 to March 11 and from November 18 to 30, 1907, by Archie J. Weith.

TABLE 134.—*Daily turbidity measurements of Osage River at Ottawa, Kans., and daily gage heights at Ottawa.*

[W. H. Blacksten, observer.]

| Day. | 1904. | | | | | | | | | | | | 1905. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June. | | August. | | September. | | October. | | November. | | December. | | January. | | February. | | March. | | April. | | May. | | June. | | July. | |
| | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. |
| 1 | 2,400 | ....... | 120 | 1.7 | 70 | 1.4 | 24 | 1.5 | 28 | 1.1 | 35 | 1.3 | 30 | 1.4 | 35 | 1.3 | 90 | 2.5 | 1,500 | 2.9 | 60 | 1.9 | 800 | 2.5 | 450 | 1.9 |
| 2 | 2,700 | ....... | 110 | 1.7 | 1,500 | 12.55 | 45 | 1.5 | 30 | 1.2 | 30 | 1.3 | 40 | 1.4 | 40 | 1.3 | 75 | 2.0 | 1,000 | 2.6 | 50 | 1.8 | 350 | 2.2 | 800 | 6.55 |
| 3 | 2,700 | 24.6 | 110 | 1.6 | 1,500 | 13.3 | 35 | 1.5 | 35 | 1.2 | 45 | 1.3 | 35 | 1.4 | 35 | 1.3 | 95 | 2.0 | 300 | 2.4 | 90 | 1.7 | 200 | 2.1 | 3,000 | 24.8 |
| 4 | 1,200 | 24.75 | 95 | 1.6 | 800 | 2.7 | 35 | 1.5 | 30 | 1.2 | 30 | 1.3 | 28 | 1.4 | 35 | 1.3 | 90 | 1.9 | 250 | 2.3 | 85 | 1.7 | 160 | 2.0 | 3,000 | 25.45 |
| 5 | 1,800 | 24.45 | 95 | 1.6 | 350 | 1.9 | 30 | 1.5 | 30 | 1.2 | 35 | 1.3 | 26 | 1.3 | 30 | 1.3 | 75 | 1.8 | 250 | 2.2 | 85 | 1.7 | 160 | 2.0 | 1,600 | 23.2 |
| 6 | 1,600 | 17.0 | 95 | 1.6 | 130 | 1.7 | 28 | 1.4 | 28 | 1.2 | 30 | 1.3 | 24 | 1.3 | 30 | 1.3 | 60 | 1.6 | 200 | 2.15 | 85 | 1.7 | 160 | 1.9 | 1,600 | 9.25 |
| 7 | 1,400 | 5.97 | 65 | 1.5 | 95 | 1.6 | 35 | 1.4 | 28 | 1.2 | 35 | 1.3 | 28 | 1.3 | 40 | 1.3 | 65 | 1.6 | 90 | 2.1 | 80 | 1.7 | 160 | 1.8 | 1,500 | 3.2 |
| 8 | 720 | 3.25 | 65 | 1.5 | 45 | 1.6 | 24 | 1.3 | 30 | 1.2 | 40 | 1.3 | 24 | 1.3 | 30 | 1.3 | 65 | 1.6 | 90 | 2.1 | 110 | 1.7 | 95 | 1.8 | 500 | 2.7 |
| 9 | 800 | 2.85 | 100 | 1.5 | 45 | 1.6 | 30 | 1.3 | 45 | 1.2 | 30 | 1.3 | 22 | 1.3 | 35 | 1.3 | 65 | 1.5 | 70 | 1.9 | 300 | 2.1 | 120 | 1.6 | 500 | 2.6 |
| 10 | 800 | 2.7 | 70 | 1.5 | 40 | 1.6 | 22 | 1.3 | 35 | 1.2 | 35 | 1.3 | 24 | 1.3 | 28 | 1.3 | 45 | 1.6 | 65 | 1.9 | 300 | 2.2 | 110 | 1.6 | 200 | 2.7 |
| 11 | 720 | 4.6 | 70 | 1.5 | 55 | 1.6 | 35 | 1.3 | 30 | 1.2 | 30 | 1.3 | 28 | 1.3 | 30 | 1.3 | 40 | 1.5 | 50 | 1.8 | 130 | 2.0 | 55 | 1.5 | 250 | 2.5 |
| 12 | 600 | 7.85 | 70 | 1.5 | 35 | 1.6 | 40 | 1.3 | 30 | 1.2 | 35 | 1.3 | 24 | 1.3 | 35 | 1.3 | 35 | 1.4 | 35 | 1.7 | 130 | 1.8 | 75 | 1.5 | 150 | 2.2 |
| 13 | 2,400 | 3.2 | 80 | 1.5 | 30 | 1.6 | 24 | 1.3 | 30 | 1.2 | 35 | 1.3 | 22 | 1.3 | 20 | 1.3 | 40 | 1.5 | 35 | 1.7 | 350 | 2.2 | 60 | 1.5 | 100 | 2.15 |
| 14 | 2,100 | 2.6 | 350 | 2.1 | 28 | 1.6 | 24 | 1.3 | 40 | 1.2 | 30 | 1.3 | 20 | 1.3 | 35 | 1.3 | 60 | 1.5 | 35 | 1.7 | 130 | 2.1 | 85 | 1.45 | 80 | 2.0 |
| 15 | 800 | 2.7 | 140 | 1.5 | 28 | 1.6 | 30 | 1.3 | 35 | 1.2 | 28 | 1.3 | 20 | 1.3 | 45 | 1.3 | 60 | 1.5 | 30 | 1.7 | 180 | 2.1 | 65 | 1.4 | 75 | 1.9 |
| 16 | 5,400 | 7.5 | 100 | 1.5 | 24 | 1.5 | 30 | 1.2 | 45 | 1.2 | 30 | 1.3 | 22 | 1.3 | 40 | 1.3 | 65 | 1.5 | 30 | 1.6 | 250 | 2.0 | 70 | 1.4 | 60 | 1.9 |
| 17 | 4,800 | 4.0 | 95 | 1.5 | 24 | 1.5 | 40 | 1.2 | 45 | 1.3 | 35 | 1.3 | 20 | 1.3 | 30 | 1.3 | 70 | 1.45 | 20 | 1.6 | 130 | 1.9 | 60 | 1.4 | 55 | 1.8 |
| 18 | 4,800 | 2.8 | 500 | 1.5 | 24 | 1.5 | 35 | 1.2 | 45 | 1.3 | 26 | 1.3 | 24 | 1.3 | 35 | 1.3 | 75 | 2.9 | 30 | 1.6 | 180 | 1.8 | 65 | 1.35 | 55 | 1.7 |
| 19 | 5,400 | 12.6 | 500 | 3.1 | 24 | 1.4 | 30 | 1.2 | 40 | 1.3 | 28 | 1.3 | 20 | 1.3 | 30 | 1.3 | 60 | 3.3 | 55 | 1.6 | 150 | 1.7 | 150 | 1.6 | 55 | 1.7 |
| 20 | 5,400 | 15.05 | 350 | 2.5 | 24 | 1.4 | 30 | 1.2 | 30 | 1.3 | 30 | 1.3 | 28 | 1.3 | 40 | 1.3 | 40 | 3.1 | 100 | 1.55 | 130 | 1.6 | 180 | 1.8 | 50 | 1.7 |
| 21 | 5,700 | 10.5 | 350 | 2.1 | 18 | 1.3 | 35 | 1.2 | 30 | 1.3 | 30 | 1.3 | 30 | 1.3 | 20 | 1.3 | 30 | 2.5 | 40 | 1.6 | 150 | 1.6 | 180 | 1.7 | 40 | 1.6 |
| 22 | 2,100 | 6.3 | 500 | 2.0 | 22 | 1.3 | 35 | 1.2 | 40 | 1.2 | 35 | 1.3 | 40 | 1.3 | 28 | 2.15 | 35 | 1.65 | 40 | 1.55 | 90 | 1.5 | 130 | 1.6 | 40 | 1.6 |
| 23 | 2,400 | 4.15 | 800 | 5.0 | 20 | 1.4 | 35 | 1.2 | 35 | 1.2 | 26 | 1.3 | 35 | 1.4 | 110 | 4.2 | 60 | 2.2 | 45 | 1.6 | 90 | 1.5 | 110 | 1.6 | 40 | 1.6 |
| 24 | ....... | 2.65 | 500 | 2.5 | 18 | 1.4 | 22 | 1.2 | 30 | 1.3 | 30 | 1.3 | 40 | 1.3 | 110 | 5.9 | 65 | 2.9 | 40 | 1.5 | 130 | 1.5 | 95 | 1.5 | 55 | 1.5 |
| 25 | ....... | 16.45 | 500 | 1.9 | 19 | 1.3 | 35 | 1.1 | 55 | 1.3 | 28 | 1.3 | 22 | 1.2 | 100 | 6.0 | 1,500 | 3.05 | 35 | 1.6 | 160 | 3.55 | 80 | 1.5 | 50 | 1.5 |
| 26 | 2,100 | 22.9 | 250 | 1.9 | 18 | 1.3 | 30 | 1.1 | 50 | 1.3 | 30 | 1.1 | 30 | 1.4 | 70 | 4.9 | 300 | 2.4 | 150 | 2.3 | 1,500 | 16.08 | 65 | 1.4 | 50 | 1.5 |
| 27 | 2,100 | 26.25 | 300 | 1.7 | 19 | 1.3 | 24 | 1.1 | 60 | 1.3 | 30 | 1.1 | 35 | 1.3 | 75 | 3.3 | 60 | 2.15 | 130 | 2.6 | 1,100 | 14.45 | 85 | 1.5 | 1,500 | 7.5 |
| 28 | 1,200 | 25.00 | 130 | 1.5 | 20 | 1.3 | 28 | 1.1 | 40 | 1.3 | 40 | 1.1 | 40 | 1.3 | 75 | 2.8 | 1,500 | 11.27 | 400 | 2.4 | 800 | 3.48 | 70 | 1.5 | 3,000 | 9.7 |
| 29 | 1,080 | 10.4 | 110 | 1.5 | 17 | 1.3 | 30 | 1.1 | 35 | 1.3 | 45 | 1.1 | 35 | 1.2 | ..... | ....... | 3,000 | 17.0 | 120 | 2.1 | 800 | 4.35 | 185 | 2.2 | 3,000 | 3.75 |
| 30 | 600 | 8.3 | 70 | 1.5 | 22 | 1.4 | 30 | 1.1 | 30 | 1.3 | 35 | 1.2 | 30 | 1.2 | ..... | ....... | 1,500 | 12.4 | 55 | 2.0 | 500 | 4.4 | 350 | 2.0 | 3,000 | 2.5 |
| 31 | ....... | ....... | 70 | 1.4 | ....... | ....... | 28 | 1.1 | .... | ..... | 30 | 1.3 | 35 | 1.3 | ..... | ....... | 1,500 | 4.2 | ....... | ....... | 1,500 | 3.2 | .... | ....... | 800 | 2.6 |
| Mean | 2,351 | ....... | 218 | .... | 169 | ....... | 31 | .... | 70 | .... | 33 | .... | 28 | .... | 45 | ..... | 349 | ....... | 176 | ...... | 317 | ...... | 151 | ...... | 828 | ...... |

NOTE.—Daily turbidity measurements of Osage River by Robert Leasure, observer, at Lacygne, Kans., and daily gage heights at Ottawa.

TABLE 135.—*Turbidity of daily samples from Osage River, at Boicourt, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
| 1 | 60 | 75 | 60 | 30 | 1,200 | 966 | 70 | 2,000 | 520 | ...... | 90 | ...... |
| 2 | 63 | 75 | 60 | 18 | 700 | 613 | 110 | 3,500 | 406 | 100 | 50 | 40 |
| 3 | 440 | 75 | 48 | 900 | 325 | 473 | 175 | 1,464 | 390 | 125 | 130 | 36 |
| 4 | 490 | 85 | 14 | 1,866 | 190 | 317 | 80 | 1,666 | 315 | 115 | 90 | 40 |
| 5 | 345 | 50 | 18 | 1,530 | 85 | 245 | 68 | 650 | 255 | 100 | ...... | 50 |
| 6 | 235 | 40 | 5 | 800 | 130 | 385 | 68 | 406 | 160 | ...... | 100 | 50 |
| 7 | 155 | 36 | 15 | 562 | 120 | 1,226 | 200 | 295 | 160 | 90 | ...... | ...... |
| 8 | 130 | 278 | 13 | 520 | 90 | 1,000 | 3,000 | 170 | 130 | 80 | 90 | 60 |
| 9 | 90 | 70 | 16 | 412 | 65 | ...... | 3,792 | 100 | 100 | 70 | 70 | 60 |
| 10 | 105 | 65 | 18 | ...... | 65 | 425 | 3,792 | 120 | 110 | 70 | ...... | 36 |
| 11 | 65 | 30 | 45 | 2,436 | 65 | 260 | 2,760 | 120 | 80 | 65 | 55 | 45 |
| 12 | 70 | 28 | ...... | 1,872 | 65 | 200 | 2,295 | 115 | 75 | 80 | 55 | 24 |
| 13 | 60 | 27 | 550 | 1,992 | 50 | 200 | 650 | 85 | 75 | ...... | 70 | 18 |
| 14 | 70 | 26 | 532 | 1,400 | 42 | 3,192 | 1,866 | 58 | 55 | 85 | 70 | ...... |
| 15 | 80 | 27 | 512 | 966 | 52 | 1,866 | 2,799 | 75 | 95 | 75 | 55 | 18 |
| 16 | 60 | 18 | 370 | 580 | 52 | 632 | 2,310 | ...... | 135 | 70 | 70 | 15 |
| 17 | 53 | 190 | 290 | 450 | 36 | 275 | 1,866 | 95 | 613 | 65 | 70 | 18 |
| 18 | 45 | 150 | 125 | 340 | ...... | 210 | 613 | 95 | 473 | 80 | 60 | 24 |
| 19 | 45 | 2,700 | 125 | 230 | 20 | 200 | 400 | 65 | 270 | 85 | 60 | 18 |
| 20 | 40 | 1,860 | 150 | 160 | 32 | 180 | 304 | 65 | 200 | 70 | 60 | 16 |
| 21 | 55 | 1,230 | 110 | 110 | 32 | 125 | 580 | 65 | 833 | ...... | 40 | 240 |
| 22 | 55 | 976 | 70 | 110 | 23 | 180 | 866 | 65 | 765 | ...... | 45 | 120 |
| 23 | 40 | 976 | 65 | 80 | 52 | 150 | 613 | 65 | 650 | 80 | 36 | 120 |
| 24 | 42 | 812 | 50 | 70 | 28 | 115 | 1,064 | 85 | 435 | 70 | 50 | 100 |
| 25 | 45 | 510 | 32 | 60 | 40 | 110 | 2,200 | 50 | ...... | 70 | 50 | 70 |
| 26 | 42 | 532 | 30 | 48 | 34 | ...... | 2,220 | 50 | 200 | 70 | 45 | 32 |
| 27 | 40 | 385 | 20 | 48 | 27 | 90 | 1,300 | 65 | 180 | 75 | 50 | 90 |
| 28 | 38 | 180 | 22 | 45 | ...... | 80 | 933 | 70 | 165 | 80 | 50 | 100 |
| 29 | ...... | 135 | ...... | 60 | 75 | 80 | 800 | 125 | 175 | 70 | 45 | 100 |
| 30 | 35 | 105 | ...... | 2,700 | 1,000 | 110 | 1,530 | 295 | 165 | 90 | 24 | 70 |
| 31 | 82 | 110 | ...... | 1,866 | ...... | 80 | ...... | ...... | 160 | ...... | 40 | ...... |
| Mean | 106 | 382 | 125 | 742 | 168 | 482 | 1,311 | 416 | 278 | 81 | 61 | 60 |

NOTE.—Turbidities over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

TABLE 136.—*Assays of water of Osage River and of its tributaries in Kansas.*

[Parts per million.]

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$) | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | |
| 1 | June 16 | Elm Creek, north of Reading [a] | 0.5 | 23 | 191 | 67 | 10 |
| 2 | ...do..... | 142 Mile Creek, northwest of Reading [a] | 1.0 | 0.0 | 282 | 85 | 7 |
| 3 | ...do..... | Duck Creek, northwest of Reading [a] | 1.5 | .0 | 170 | 106 | 7 |
| 4 | June 17 | Osage River, at Reading [a] | Trace. | .0 | 216 | 132 | 10 |
| 5 | June 16 | Cherry Creek, 4 miles east of Reading [b] | .5 | 10.0 | 263 | 116 | 15 |
| 6 | ...do..... | Cole Creek, southwest of Arvonia [a] | .0 | .0 | 299 | 215 | 15 |
| 7 | June 19 | Osage River, at Melvern | 3.0 | Trace. | 202 | 72 | 11 |
| 8 | ...do..... | Long Creek, east of Melvern [a] | 1.2 | .0 | 251 | 71 | 10 |
| 9 | June 20 | Osage River, at Quenemo [a] | 1.2 | .0 | 252 | 48 | 10 |
| | 1907. | | | | | | |
| 10 | Aug. 22 | Rock Creek, at Waverly | .0 | .0 | 174 | Trace. | 14 |
| 11 | June 19 | Rock Creek, at Melvern [a] | 1.0 | .0 | 292 | 46 | 7 |
| 12 | ...do..... | Tugua Creek, southwest of Quenemo [a] | .5 | Trace. | 294 | 53 | 7 |
| | 1905. | | | | | | |
| 13 | June 14 | Salt Creek, at Osage City | .0 | 11 | 232 | 191 | 15 |
| 14 | June 20 | Salt Creek, north of Quenemo [a] | .0 | .0 | 299 | 44 | 71 |
| 15 | ...do..... | Osage River below Salt Creek, east of Lomax [a] | .0 | .0 | 299 | 37 | 71 |
| 16 | June 13 | Dragoon Creek above confluence with Soldier Creek | .0 | .0 | 293 | 76 | 14 |
| 17 | ...do..... | Soldier Creek above confluence with Dragoon Creek | .0 | Trace. | 261 | 101 | 10 |

[a] By Edward Bartow. [b] In pools; not running. By Edward Bartow.

TABLE 136.—*Assays of water of Osage River and of its tributaries in Kansas*—Continued.

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$) | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | |
| 18 | June 13 | Dragoon Creek, above confluence with Switzler Creek | Trace. | 11 | 279 | 94 | 14 |
| 19 | ...do..... | Hoover Creek, above Switzler Creek, at Burlingame | .0 | .0 | 271 | 136 | 35 |
| 20 | ...do..... | Switzler Creek, above Burlingame and above Hoover Creek | .0 | .0 | 98 | 54 | 14 |
| 21 | ...do..... | Switzler Creek, above Dragoon Creek | .0 | Trace. | 249 | 82 | 14 |
| 22 | ...do..... | Dragoon Creek, one-fourth mile below Switzler Creek | Trace. | .0 | 266 | 116 | 14 |
| 23 | ...do..... | School Creek | Trace. | .0 | 302 | 215 | 14 |
| 24 | ...do..... | Popcorn Creek | .0 | .0 | 302 | 108 | 10 |
| 25 | July 30 | Stream from old mines at Scranton [a] | 1.2 | .0 | 338 | ........ | 89 |
| 26 | June 20 | Dragoon Creek, east of Lomax [b] | .5 | .0 | 256 | 52 | 15 |
| 27 | ...do..... | Osage River, below Dragoon Creek [b] | .0 | .0 | 279 | 46 | 20 |
| 28 | June 17 | Wilson Creek, west of Ottawa | .0 | .0 | 232 | 127 | 25 |
| 29 | June 16 | Muddy Creek, west of Ottawa | .0 | .0 | 251 | 40 | 14 |
| 30 | ...do..... | Appanoose Creek, west of Ottawa | .0 | 12.0 | 267 | 41 | 10 |
| 31 | ...do..... | Eight Mile Creek, west of Ottawa | .0 | .0 | 256 | 68 | 14 |
| 32 | June 17 | Middle Creek, east of Ottawa | .0 | Trace. | 228 | Trace. | 10 |
| 33 | ...do..... | Ottawa Creek, above Peoria | .0 | .0 | 232 | Trace. | 15 |
| 34 | June 15 | Osage River, at Ottawa, above sewer outlets and below gas house | .0 | .0 | 251 | 67 | 25 |
| 35 | June 17 | Osage River, at highway bridge between Imes and Peoria | .0 | .0 | 228 | 71 | 25 |
| 36 | June 22 | Kenoma Creek, 8.5 miles west and 2 miles north of Garnett [b] | .0 | .0 | 154 | 89 | 7 |
| 37 | ...do..... | North Pottawatomie Creek, 8 miles west and 2 miles north of Garnett [b] | .0 | .0 | 174 | Trace. | 12 |
| 38 | ...do..... | Iantha Creek, 1 mile west and 4 miles north of Glenloch [b] | .0 | .0 | 180 | Trace. | 5 |
| 39 | ...do..... | Sac Creek, 3 miles west and 3 miles south of Richmond [b] | Trace. | .0 | 110 | Trace. | 7 |
| 40 | ...do..... | Cedar Creek, west of Garnett [b] | .0 | .0 | 199 | Trace. | 5 |
| 41 | ...do..... | Pottawatomie Creek, 2 miles west and 5 miles north of Garnett [b] | .0 | .0 | 173 | Trace. | 9.7 |
| 42 | June 23 | South Fork Pottawatomie Creek, above Greeley [b] | Trace. | .0 | 201 | Trace. | 15 |
| 43 | ...do..... | North Pottawatomie Creek, 2.5 miles west of Greeley, above South Fork [b] | .0 | .0 | 213 | Trace. | 7 |
| 44 | ...do..... | Pottawatomie Creek, one-half mile west and 1½ miles north of Greeley [b] | .0 | .0 | 202 | Trace. | 20 |
| 45 | June 22 | Pottawatomie Creek, at Osawatomie, three-fourths mile from mouth | .0 | .0 | 206 | ........ | 10 |
| | 1907. | | | | | | |
| 46 | Apr. 23 | Pottawatomie Creek, at Osawatomie, at bridge near Missouri Pacific Ry. roundhouse [c] | .0 | .0 | 254 | Trace. | 14 |
| | 1905. | | | | | | |
| 47 | June 22 | Plum Creek, one-half mile from mouth [d] | .0 | .0 | 251 | ........ | 10 |
| 48 | ...do..... | Osage River, at waterworks intake, Osawatomie | .5 | .0 | 105 | Trace. | 10 |
| 49 | ...do..... | Osage River, south of Paola, above Bull Creek. | Trace. | .0 | 130 | Trace. | 10 |
| 50 | June 23 | Big Bull Creek, above Little Bull Creek, north of Paola | Trace. | .0 | 88 | Trace. | 5 |
| 51 | ...do..... | Little Bull Creek, 6½ miles north of Paola | .0 | Trace. | 256 | Trace. | 10 |
| 52 | ...do..... | Big Bull Creek, above Ten Mile Creek, north of Paola | Trace. | 12 | 171 | Trace. | 10 |
| 53 | ...do..... | Ten Mile Creek, 4 miles north of Paola | .0 | .0 | 225 | Trace. | 10 |
| 54 | ...do..... | Walnut Creek, 1½ miles northwest of Paola | Trace. | .0 | 235 | Trace. | 10 |
| 55 | ...do..... | Bull Creek, at Bridge Street bridge, south of Paola [e] | .0 | .0 | 190 | Trace. | 15 |
| | 1907. | | | | | | |
| 56 | Apr. 22 | .....do | .0 | .0 | 234 | Trace. | 10 |
| | 1905. | | | | | | |
| 57 | June 22 | South Wea Creek, above North Wea Creek, northeast of Paola | .0 | .0 | 217 | Trace. | 10 |
| 58 | ...do..... | North Wea Creek, above South Wea Creek, northeast of Paola | .0 | Trace. | 247 | Trace. | 12 |
| 59 | ...do..... | Wea Creek, three-fourths mile above mouth, southeast of Paola | .0 | .0 | 238 | Trace. | 10 |
| 60 | ...do..... | Bull Creek, one-fourth mile above mouth, south of Paola | .0 | .0 | 184 | Trace. | 10 |
| 61 | June 25 | Osage River, at St. Louis & San Francisco Ry. bridge, northwest of Lacygne | .0 | .0 | 160 | Trace. | 20 |

[a] By Edward Bartow. $SO_4$ above 626.
[b] By Edward Bartow.
[c] Rain night of 22d.
[d] Stagnant.
[e] Creek streaked with oil.

TABLE 136.—*Assays of water of Osage River and of its tributaries in Kansas*—Continued.

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$) | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | |
| 62 | June 25 | Hushpuckney Creek, below Middle Creek, 2½ miles north and 3 miles west of Lacygne [a] | 0.0 | 0.0 | 283 | Trace. | 12 |
| 63 | ...do..... | Elm Creek, one-half mile north and 4½ miles west of Lacygne [b] | .0 | .0 | 251 | Trace. | 4.6 |
| 64 | ...do..... | Osage River, at bridge at Lacygne [b] | .0 | .0 | 256 | 36 | 30 |
| 65 | ...do..... | Middle Creek, 1¼ miles east of Lacygne [b] | .0 | .0 | 283 | Trace. | 10 |
| 66 | June 26 | Lake, at Boicourt [b] | .0 | .0 | 149 | Trace. | 4.6 |
| 67 | June 25 | Sugar Creek, 6 miles east of Lacygne [b] | .0 | Trace. | 271 | Trace. | 10 |
| 68 | June 26 | Osage River, below Sugar Creek [b] | .0 | Trace. | 239 | Trace. | 30 |
| 69 | ...do..... | Little Sugar Creek, southwest of Boicourt [b] | .0 | .0 | 266 | Trace. | 12 |
| 70 | ...do..... | Big Sugar Creek, southwest of Boicourt [b] | .0 | .0 | 189 | Trace. | 7 |
| 71 | ...do..... | Mine Creek, southeast of Pleasanton [b] | .0 | Trace. | 271 | Trace. | 7 |
| 72 | June 27 | Marmaton River, one-fourth mile above Pawnee Creek, southwest of Fort Scott | Trace. | .0 | 243 | Trace. | 6 |
| 73 | ...do..... | Pawnee Creek, above Yellow Paint Creek, south of Marmaton | .0 | .0 | 232 | Trace. | 10 |
| 74 | ...do..... | Yellow Paint Creek, above Pawnee Creek, south of Marmaton | .0 | .0 | 232 | Trace. | 6 |
| 75 | ...do..... | Pawnee Creek, below Yellow Paint Creek, south of Marmaton | .0 | Trace. | 235 | Trace. | 6 |
| 76 | ...do..... | Marmaton River, at waterworks intake, Fort Scott | Trace. | 11 | 177 | Trace. | 20 |
| 77 | ...do..... | Mill Creek, near mouth, Fort Scott | .0 | 12 | 216 | 62 | 12 |
| 78 | ...do..... | Buck Creek, at Missouri Pacific Ry. track, Fort Scott | .0 | .0 | 279 | 287 | 66 |
| 79 | ...do..... | Marmaton River, below Buck Creek, Fort Scott | .5 | .0 | 282 | 132 | 63 |
| 80 | ...do..... | Rock Creek, at mouth, Fort Scott | .5 | .0 | 335 | ........ | 132 |
| 81 | ...do..... | West Fork of Dry Wood Creek, southwest of Garland [b] | .0 | .0 | 171 | 61 | 4 |
| 82 | ...do..... | Cox Creek, at St. Louis & San Francisco pumping station, Arcadia [b] | .0 | .0 | 101 | 140 | 4 |
| 83 | ...do..... | Buck Run, 1½ miles west and 1 mile south of Garland [b] | .0 | .0 | 239 | 97 | 6 |
| 84 | ...do..... | Clever Creek, 2 miles west of Fulton [c] | Trace. | .0 | 46 | Trace. | 6 |
| 85 | ...do..... | Little Osage River, northeast of Fulton [c] | .0 | .0 | 83 | Trace. | 6 |
| 86 | July 1 | Fish Creek, ½ mile south of Fulton | Trace. | .0 | 66 | Trace. | 6 |

[a] At Achey Ford. By Edward Bartow. [b] By Edward Bartow. [c] In flood.

NOTE.—Trace in the sulphate column means less than 35 parts per million.

TABLE 137.—*Analyses of water from Osage River and its tributaries in Kansas.*

[Parts per million.]

| No. | Date. | Source. | Analyst. | Silica. | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$).[a] | Sulphate ($SO_4$). | Chlorine (Cl). | Organic and volatile. | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ........ | Elm Creek, at Miller | Missouri Pacific Ry | 14 | 0.8 | 65 | 14 | 16 | 114 | 58 | 6.7 | 14 | ........ |
| 2 | Nov. 15, 1902 | Osage River, at Reading | Atchison, Topeka & Santa Fe Ry. | 18 | 12 | 92 | 21 | 9.8 | 151 | 39 | 16 | ........ | ........ |
| 3 | Sept. 22, 1903 | Osage River, at Quenemo | .....do | 19 | ........ | 102 | 15 | 13 | 149 | 79 | 7.2 | 51 | 435 |
| 4 | Nov. 15, 1902 | .....do | .....do | 18 | .8 | 100 | 17 | 6.3 | 164 | 45 | 9 | ........ | ........ |
| 5 | Oct. 5, 1899 | Pond made by dam across Salt Creek at Osage City. | .....do | ........ | ........ | 180 | 42 | 55 | 104 | 511 | 25 | 187 | 1,106 |
| 6 | Nov. 15, 1902 | Salt Creek, at Osage | Kennicott Water Softener Co. | 14 | 1.4 | 114 | 44 | ........ | 189 | 86 | 44 | ........ | ........ |
| 7 | ........ | Salt Creek, at Lomax | Missouri Pacific Ry | 27 | 1.7 | 71 | 12 | 25 | 112 | 52 | 28 | 22 | 329 |
| 8 | Nov. 15, 1902 | Dragoon Creek, at Harveyville | Atchison, Topeka & Santa Fe Ry. | 4.8 | 9.5 | 104 | 20 | 17 | 190 | 47 | 12 | ........ | ........ |
| 9 | Dec. 20, 1906 | Dragoon, between Burlingame and Osage, 50 feet west of bridge. | .....do | ........ | ........ | 89 | ........ | 38 | 133 | 57 | 17 | ........ | 334 |
| 10 | .....do | Dragoon Creek, between Burlingame and Osage, 150 feet east of bridge. | .....do | ........ | ........ | 100 | ........ | 32 | 149 | 42 | 19 | ........ | 341 |
| 11 | Nov. 15, 1902 | Osage River, at North Ottawa | .....do | 60 | .2 | 34 | 3.8 | 13 | 44 | 22 | 30 | ........ | ........ |
| 12 | Nov. 7, 1902 | Osage River, at Ottawa | .....do | 16 | .7 | 62 | 8 | 15 | 90 | 40 | 18 | ........ | ........ |
| 13 | ........ | Osage River (city waterworks), at Ottawa. | Missouri Pacific Ry | 23 | 3.1 | 59 | 9.3 | 5.7 | 91 | 31 | 8.7 | 20 | 252 |
| 14 | ........ | Osage River, at Osawatomie | .....do | 16 | .8 | 87 | 12 | 16 | 150 | 36 | 11 | ........ | 352 |
| 15 | ........ | North Pottawatomie Creek, at Glenlock. | .....do | 11 | 5.2 | 84 | 16 | 17 | 152 | 44 | 7.9 | 14 | 352 |
| 16 | Nov. 7, 1902 | Pond, at Garnett | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 95 | 9.5 | 6.6 | 76 | 117 | 31 | ........ | ........ |
| 17 | ........ | Ponds (city waterworks), at Garnett. | .....do | 9.9 | 2.2 | 43 | 5.3 | 8.3 | 66 | 24 | 8.3 | 19 | 188 |
| 18 | Nov. 15, 1902 | Pond, at Edgerton | .....do | 6.5 | 4.5 | 34 | 7.6 | 17 | 62 | 26 | 17 | ........ | ........ |
| 19 | May 4, 1903 | .....do | .....do | 22 | ........ | 34 | 5.9 | 10 | 37 | 57 | 7.3 | 69 | 241 |
| 20 | May 3, 1902 | Bull Creek, 7 miles south of Edgerton. | .....do | ........ | ........ | 46 | 7.4 | 7.3 | 83 | 14 | 6.2 | 46 | 217 |
| 21 | ........ | Bull Creek (city waterworks), at Paola. | .....do | 11 | .8 | 41 | 8 | 6.9 | 69 | 25 | 6.2 | 9.2 | 178 |
| 22 | ........ | Sugar Creek, at Sugar Creek | Missouri Pacific Ry | 23 | 2.2 | 60 | 7.8 | 1.8 | 97 | 19 | 2.8 | 18 | 233 |
| 23 | ........ | Little Osage River, at Harding | .....do | 13 | 1.8 | 50 | 12 | 16 | 87 | 51 | 6.3 | 17 | 254 |

[a] Obtained by computation to ionic form; results originally stated as in hypothetical combinations.

## MARMATON RIVER.

A daily sampling station was maintained by the United States Geological Survey on Marmaton River at Fort Scott from February 1, 1907, to February 10, 1908. James Burton was collector.

The results of the analyses of composite samples appear in Table 138. These analyses cover a period of one year and show a calcic alkaline water of moderate temporary and low permanent hardness. The chlorides are low.

The turbidity of the daily samples is recorded in Table 139. Three hundred and seventeen readings are entered; over 91 per cent of these are less than 50, and but a fraction over 1 per cent were 100 or more. The turbidity from February 1, 1907, to January 17, 1908, was low. During February, March, and April the turbidity was never greater than 20, and much of this time it was less than 10. The river was most turbid during May and June, and the turbidity fluctuated considerably. From July to the end of the period the turbidity was low, rising above 50 only three times. The highest turbidity recorded was 295 on June 14, and the lowest 3, which was noted several times. The coefficient of fineness, Table 138, varies considerably, but much of the time was so low as to indicate that provision should be made for the use of a coagulant in filtration works designed to purify the water for public consumption.

Tests of the water of Marmaton River and its tributaries at and above the waterworks at Fort Scott appear in assays 72 to 76, Table 136. The waters of these streams have moderate temporary and low permanent hardness and low chlorides, just as most of the other tributaries of the Osage have. The waters of Mill Creek and Buck Creek, which enter Marmaton River below the waterworks, are shown by assays 77 and 78, Table 136, to be high in sulphates, which are apparently derived from the coal-measure shales. The effect of these tributaries on the water of Marmaton River is shown by assay 79, Table 136. Tests of tributaries of Drywood Creek, assays 81, 82, and 83, Table 136, show that these streams likewise are sulphated by the shales. Tests of Little Marmaton River and its tributaries at a time when they are in flood (assays 84, 85, and 86, Table 136) show very soft waters, but in no wise represent the quality of the water in these streams when they are at normal stage.

TABLE 138.—*Analyses of water from Marmaton River at Fort Scott, Kans.*

[Drainage area 360 (estimated) square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1907. | 1907. | | | | | | | | | | | | | | |
| Feb. 1 | Feb. 10 | 15 | 9 | 0.60 | 16 | 3.2 | 84 | 3.3 | 21 | 0.0 | 257 | 38 | 6.0 | 10 | 277 |
| Feb. 11 | Feb. 20 | 7 | 8 | 1.14 | 16 | .24 | 89 | 7.6 | 21 | .0 | 283 | 41 | 3.5 | 4.0 | 297 |
| Feb. 21 | Mar. 2 | 8 | 5 | .62 | 70 | .10 | 91 | 5.5 | 30 | *a* 8.0 | 256 | 45 | 2.3 | 4.2 | 366 |
| Mar. 3 | Mar. 12 | 11 | 5.4 | .49 | 48 | .36 | 88 | 7.5 | 29 | *a* 6.7 | 246 | 44 | .7 | 4.1 | 344 |
| Mar. 13 | Mar. 22 | 7 | 4 | .57 | 4 | 1.0 | 85 | 8.3 | 17 | .0 | 250 | 43 | .2 | 4.1 | 268 |
| Mar. 23 | Apr. 1 | 9 | 3.4 | .38 | 1.5 | .6 | 83 | 1.6 | 23 | .0 | 229 | 43 | .1 | 4.6 | 280 |
| Apr. 2 | Apr. 11 | 15 | 9 | .60 | 8.0 | 1.5 | 77 | 9.3 | 18 | .0 | 240 | 46 | .6 | 2.3 | 268 |
| Apr. 12 | Apr. 21 | 12 | 6.4 | .53 | 5.4 | 1.2 | 96 | 1.3 | 16 | .0 | 287 | 47 | .4 | 6.0 | 294 |
| Apr. 22 | May 1 | 12 | 4.4 | .37 | 2.6 | 1.4 | 94 | 1.3 | 20 | .0 | 280 | 45 | .7 | 7.5 | 291 |
| May 2 | May 11 | 58 | 57 | .98 | 8.4 | 5.0 | 67 | 2.9 | 20 | .0 | 181 | 38 | 5.5 | 3.5 | 224 |
| May 12 | May 21 | 54 | 58 | 1.07 | 15 | 3.5 | 67 | 6.9 | 14 | .0 | 205 | 33 | 4.5 | 4.0 | 238 |
| May 23 | June 3 | 14 | 4 | .28 | 10 | 1.5 | 86 | 3.7 | 25 | .0 | 285 | 36 | 3.2 | 5.5 | 274 |
| June 4 | June 13 | 23 | 16 | .70 | 13 | 1.0 | 89 | 8.5 | 21 | .0 | 280 | 34 | 1.9 | 6.0 | 270 |
| June 14 | June 25 | 80 | 53 | .66 | 18 | 2.0 | 65 | 23 | 36 | .0 | 172 | 34 | 7.2 | 2.0 | 296 |
| June 26 | July 5 | 44 | 37 | .84 | 18 | 5 | 59 | 8.6 | 18 | .0 | 178 | 24 | 4.0 | 2.5 | 205 |
| July 6 | July 15 | 22 | 17 | .77 | 12 | 3 | 73 | 19 | 23 | .0 | 235 | 27 | 2.6 | 2.0 | 226 |
| July 16 | July 29 | 20 | 11 | .55 | 14 | 1.5 | 58 | 12 | 19 | *a*14 | 240 | 28 | 1.8 | 5.5 | 196 |
| July 30 | Aug. 9 | 22 | 15 | .68 | 9.0 | 1.0 | 80 | 11 | 23 | .0 | 280 | 28 | 1.0 | 4.0 | 257 |
| Aug. 10 | Aug. 26 | 15 | 0 | ...... | 12 | .8 | 79 | 11 | 37 | .0 | 260 | 26 | .7 | 5.0 | 251 |
| Aug. 27 | Sept. 6 | 13 | 2.0 | .15 | 9.0 | .11 | 84 | 11 | 19 | *a* 3.0 | 260 | 21 | .7 | 4.0 | 242 |
| Sept. 8 | Sept. 19 | 12 | 8.6 | .72 | 10 | .04 | 79 | 9.7 | 18 | .0 | 258 | 20 | .9 | 5.4 | 247 |
| Sept. 20 | Oct. 5 | 17 | 3.6 | .21 | 10 | .04 | 83 | 14 | 28 | .0 | 290 | 34 | .0 | 5.5 | 289 |
| Oct. 7 | Oct. 20 | 17 | 6.0 | .35 | 5.2 | .02 | 83 | 12 | 20 | .0 | 270 | 25 | 1.5 | 6.5 | 257 |
| Oct. 21 | Oct. 31 | 10 | 4 | .40 | 14 | .10 | 89 | 11 | 20 | .0 | 285 | 24 | .6 | 7.0 | 279 |
| Nov. 1 | Nov. 10 | 14 | 6.4 | .46 | 11 | .13 | 86 | 9.8 | 21 | .0 | 278 | 29 | 1.0 | 7.0 | 273 |
| Nov. 11 | Nov. 20 | 11 | 4 | .36 | 11 | .14 | 88 | 10 | 15 | .0 | 265 | 21 | .5 | 7.0 | 266 |
| Nov. 21 | Dec. 3 | 12 | 3.4 | .28 | 9.0 | .12 | 79 | 10 | 24 | .0 | 255 | 24 | .5 | 6.5 | 265 |
| Dec. 4 | Dec. 15 | 13 | 3.0 | .23 | 11 | .06 | 94 | 9.2 | 26 | .0 | 275 | 21 | .5 | 7.0 | 258 |
| Dec. 17 | Dec. 26 | 14 | 6.6 | .47 | 9.0 | .14 | 76 | 8.7 | 25 | .0 | 250 | 32 | .6 | 6.0 | 259 |
| | 1908. | | | | | | | | | | | | | | |
| Dec. 17 | Jan. 7 | 36 | 18 | .50 | 18 | .40 | 78 | 7.8 | 23 | .0 | 213 | 37 | 3.0 | 5.5 | 236 |
| 1908. | | | | | | | | | | | | | | | |
| Jan. 8 | Jan. 17 | 42 | 34 | .81 | 18 | .6 | 74 | 6.8 | 25 | .0 | 218 | 51 | 2.0 | 4.5 | 252 |
| Jan. 18 | Jan. 27 | 45 | 13 | .29 | 14 | .25 | 89 | 7.8 | 20 | .0 | 220 | 48 | 2.0 | 5.0 | 264 |
| Jan. 28 | Feb. 9 | 12 | 7.6 | .63 | 11 | .40 | 82 | 8.0 | 30 | .0 | 250 | 52 | 2.1 | 5.9 | 289 |
| Feb. 10 | Feb. 19 | 32 | 35 | 1.10 | 14 | .18 | 81 | 7.5 | 24 | .0 | 245 | 48 | 1.7 | 6.0 | 277 |
| Mean........ | | 22 | 14 | .55 | 14 | 1.1 | 81 | 8.7 | 23 | .0 | 251 | 35 | 1.9 | 5.2 | 267 |
| Per cent of anhydrous residue..... | | .... | ..... | ...... | 4.8 | .5 | 27.5 | 3.0 | 7.8 | 42.1 | ...... | 11.9 | .6 | 1.8 | .... |

*a* Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from February 11 to March 12, 1907, and from December 4, 1907, to February 19, 1908, by Archie J. Weith; from March 13 to December 3, 1907, by F. W. Bushong.

TABLE 139.—*Turbidity of daily samples from Marmaton River at Fort Scott, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | 1907. | | | | | | | | | | | Jan., 1908. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | |
| 1 | 10 | 14 | 9 | 28 | 13 | 30 | 14 | 18 | 10 | 16 | 8 | 50 |
| 2 | 4 | 6 | 11 | 45 | 14 | 34 | 24 | 12 | 8 | 10 | 10 | ...... |
| 3 | 20 | 10 | 16 | 50 | 16 | 62 | 25 | 10 | ...... | 10 | 12 | 45 |
| 4 | 12 | 9 | 10 | 45 | 18 | 55 | 13 | 8 | ...... | 18 | 15 | 50 |
| 5 | 18 | 12 | 18 | 36 | 24 | 50 | 13 | 5 | 12 | 8 | 10 | 45 |
| 6 | 20 | 8 | 18 | 38 | 10 | 40 | 26 | 16 | ...... | 18 | 12 | 32 |
| 7 | 20 | 10 | 18 | 36 | 15 | 34 | ...... | ...... | 8 | 15 | 15 | 40 |
| 8 | 15 | 10 | 13 | 90 | 10 | 24 | 22 | 10 | 16 | 10 | 8 | 40 |
| 9 | 14 | 6 | 15 | 100 | 9 | 15 | 22 | 8 | ...... | 16 | 12 | 40 |
| 10 | 14 | 14 | 13 | 80 | 16 | 22 | 14 | 16 | 12 | 15 | 8 | 60 |
| 11 | 9 | 15 | 13 | 60 | 14 | 25 | 14 | 15 | 45 | 8 | 15 | 45 |
| 12 | 9 | 15 | 17 | 24 | 50 | 12 | 15 | 10 | 32 | 10 | 16 | 45 |
| 13 | 8 | 8 | 13 | 32 | 65 | 24 | 18 | 8 | ...... | 15 | 16 | 50 |
| 14 | 3 | 7 | 13 | 60 | 295 | 9 | 18 | 18 | 16 | 16 | ...... | 50 |
| 15 | 10 | 14 | 14 | 36 | 210 | 15 | 15 | 12 | 10 | 10 | 18 | 40 |
| 16 | 5 | 7 | 9 | 70 | 85 | 12 | ...... | 18 | 12 | 8 | ...... | 18 |
| 17 | 5 | 5 | 13 | 125 | 55 | 15 | ...... | 12 | ...... | 10 | 5 | 36 |
| 18 | 3 | 3 | 14 | 75 | 50 | 9 | ...... | 10 | 18 | 8 | 12 | ...... |
| 19 | 5 | 5 | 10 | 55 | ...... | 18 | ...... | 10 | 10 | 10 | 15 | ...... |
| 20 | 5 | 7 | 9 | 34 | 34 | 15 | ...... | 16 | 10 | 12 | 12 | ...... |
| 21 | 5 | 5 | 3 | 32 | ...... | 7 | 18 | ...... | 8 | 10 | 30 | ...... |
| 22 | 3 | 8 | 9 | ...... | 18 | ...... | ...... | ...... | 12 | 15 | 15 | ...... |
| 23 | 6 | 8 | 13 | 15 | 15 | ...... | 15 | ...... | 12 | ...... | 8 | ...... |
| 24 | 6 | 9 | 8 | 12 | 25 | ...... | 10 | 20 | 16 | 10 | 15 | ...... |
| 25 | 5 | 9 | 3 | 5 | 22 | ...... | ...... | 30 | 12 | 8 | 16 | ...... |
| 26 | 11 | 9 | 5 | 8 | 65 | 22 | 12 | 16 | 8 | 24 | 8 | ...... |
| 27 | 16 | 14 | 10 | 15 | 18 | 27 | 15 | 12 | 5 | 16 | 12 | ...... |
| 28 | 7 | 8 | 8 | 16 | 26 | 26 | 16 | 30 | 5 | 18 | 24 | ...... |
| 29 | ...... | 10 | 9 | 5 | 55 | 45 | 16 | 16 | 8 | 5 | 24 | ...... |
| 30 | ...... | 13 | 9 | 12 | 47 | 32 | ...... | 15 | ...... | ...... | 36 | ...... |
| 31 | ...... | 13 | ...... | ...... | ...... | 31 | 18 | ...... | 10 | ...... | ...... | ...... |
| Mean | 10 | 9 | 11 | 43 | 46 | 26 | 17 | 14 | 13 | 12 | 14 | 43 |

NOTE.—Averages: January 18 to 27, 45; January 28 to February 9, 12. Turbidities over 50 were determined with a Jackson turbidimeter, and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

## ARKANSAS RIVER DRAINAGE BASIN

### Arkansas River.

#### DESCRIPTION.

Arkansas River is formed near Leadville, Colo., by the union of three small streams—East, Lake, and Tennessee forks—that derive their waters from the melting of the almost perpetual snow which mantles the high peaks of the Saguache, Sangre de Cristo, and Culebra Ranges. From the junction of the forks the river flows a little east of south for about 75 miles, then turns to the east and cuts through a canyon whose perpendicular walls attain elevations of over 2,000 feet above the water's edge, emerging finally on the plains near Canon City; from Canon City to the Colorado-Kansas State line its general course is eastward for about 200 miles.

Entering Kansas a short distance west of Coolidge, the river runs for 140 miles by general course a little south of east, passing across Hamilton, Kearny, Finney, and Gray counties to a point east of Ford, in Ford County, where it turns and flows northeastward across

Edwards and Pawnee counties to Barton County. There it swings in a broad curve, known as the Great Bend, to the east and southeast, traversing Rice, Reno, Harvey, Sedgwick, Sumner, and Cowley counties. Southeast of Davidson, in Cowley County, it passes into Kay County, Okla., beyond which it continues its southeasterly course to its junction with the Mississippi in northern Arkansas. The entire length of the stream from source to mouth, measured along the general course, is about 1,100 miles. Its drainage area comprises approximately 188,000 square miles, of which 44,500 square miles are above Arkansas City, Kans.

For about 120 miles from its source the river is a typical mountain torrent, descending in this distance from an elevation of 10,100 feet to about 5,300 feet above sea level. Its waters are clear and its bed is rocky. As it enters the plains region its gradient diminishes, its breadth increases, it becomes unable at ordinary stages to carry the load of detritus collected in the more rapid portion above, and this detritus is gradually deposited, forming low, sandy banks and bars, which block the course and cause the stream to shift its bed. At high stage this material is again caught up. The banks are eaten away, and very considerable changes of channel result from a single flood. The lower course of the river is bordered by wide alluvial bottom lands, and the valley gradually merges with the valley of the Mississippi. From Coolidge to the eastern edge of Ford County, Kans., the flood plain of the Arkansas averages 3 miles in width, and is limited on the north by a somewhat abrupt bluff line, which is prominent throughout the whole district, except for a few miles in the vicinity of Garden. From Coolidge southeastward to Hartland the north bluff is composed of the Benton group; below Hartland it is made up of Tertiary deposits. The "mortar beds" are well developed through the greater part of this distance and, as they offer strong resistance to erosion, produce unusually abrupt bluffs.

From the eastern part of Ford County to the vicinity of Larned bluff lines are scarcely noticeable on the north side of the river. From Larned to beyond Great Bend the Dakota sandstone and the Benton group, which overlies it, form considerable bluffs some distance back from the river. As the river bears to the east and finally to the southeast near Great Bend, the width of the valley between the river and the Cretaceous bluffs greatly increases. For some distance below Great Bend to the vicinity of Wichita, and even through the remainder of the State, there is but little demarcation of the flood plain, the whole area being one great expanse of level country on both sides of the river.

On the south side of the river from Coolidge to Great Bend conditions differ greatly from those on the north, for a row of sand hills limits the valley throughout the entire distance, the elevation of the sand hills and the plains beyond averaging as great as that of the uplands on the north of the river. Thus the sand hills are usually a little higher than the plains south of them. The width of the sand hills is variable; in places they are not more than 3 or 4 miles wide; elsewhere they stretch away southward 15 or 20 miles. Such an unusual southern extension of the hills occurs in the southern part of Finney and southwestern part of Haskell counties, where the sand hills reach almost to Cimarron River. Again, in the eastern part of Haskell County, there is another long southward extension, reaching from 10 to 12 miles south of the river. Beyond the eastern limit of Ford County the sand hills become less prominent, but they are nevertheless very noticeable all the way from near Bucklin to almost opposite Great Bend, where they gradually disappear.

From Great Bend to Wichita and thence to Arkansas City the whole area on the right bank of the river is covered with an exceedingly sandy silt which here and there is blown into a series of sand dunes, approaching in character the sand hills to the west, but not equaling them in size. This fine sand between Wichita and Arkansas City appears to have been derived from the weathering of Dakota sandstone.

The Arkansas River valley was formerly much deeper than it now is. The filling-in process has been in operation sufficiently long to raise the channel of the stream to the level of its flood plain and doubtless has raised very appreciably the general level of the flood plain. There is ample evidence that at one time the river valley was from 50 to 100 feet deeper than it now is. Within the last fifteen years very noticeable filling-in has occurred. Eight to twelve years ago, when the several bridges that cross the river at different places were constructed, it was possible for a man sitting erect on horseback to ride under most of them, but the sands have since accumulated to such a depth that few of the bridges are more than 3 to 6 feet above the top of the sands. The accumulation of the sand is not due to the presence of the bridge, for the sand under the bridge is at the same level as that above and below it. Throughout the greater part of the course of the river in western Kansas the recent filling-in process has been going on, particularly on the south side of the river. From the Kansas-Colorado State line to Arkansas City marks of many old channels are seen in the valley, and it is apparent that the stream has shifted from bluff to bluff along its channel many times and that in doing so it has gradually built up its flood plain.

One of the most noteworthy features of Arkansas River is the great and unusual bend it makes in passing from eastern Ford County far to the north to Great Bend and back again far to the south. This is probably accounted for by the fact that at the eastern edge of Ford County the river encountered the easily-eroded Dakota sandstone and attacked it with great vigor, following it as far north as Great Bend, where the Flint Hills compelled the river to turn southward. It is likely that before it reached the Dakota sandstone at the eastern edge of Ford County, the river passed eastward from Ford County across the north of Kiowa, Pratt, and Kingman counties and out of the State not far from the point where it now does. To-day, in summer, Arkansas River through much of its course in the western part of the State dwindles to an insignificant stream or disappears entirely in the gravels which have accumulated in its bed, in which an abundant supply of water is at all times to be found.[1]

The water in the bed of the Arkansas in Kansas was believed by the pioneers to come from Colorado, but this theory has been abandoned, one of the principal reasons being that the bedrock of the river comes near the surface at the Colorado-Kansas State line and precludes Colorado as a source of underground water. The underflow has its origin in the rainfall on the sand hills south of the river and on the bottom lands and bluffs north of the river. Careful investigations of the underflow in Arkansas Valley in western Kansas were conducted by Charles S. Slichter in the summer of 1904.[2] The principal conclusions reached by Slichter were:

1. The underflow of Arkansas River moves at an average rate of 8 feet in 24 hours in the general direction of the valley.
2. The water plane slopes to the east at a rate of 7.5 feet per mile, and toward the river at a rate of 2 to 3 feet per mile.
3. The moving ground water extends for several miles north from the river valley. No north or south limit was found.
4. The rate of movement was very uniform.
5. The sand hills constitute an essential part of the catchment area.
6. The influence of the floods upon the ground-water level does not extend one-half mile north or south of the channel.
7. A heavy rain contributes more to the underflow than is contributed by a flood in the river.
8. On the sandy bottom lands 60 per cent of an ordinary rain reaches the water plane as a permanent contribution.
9. No indication of a decrease in the underflow has been noted in the last five years. The city wells showed the same specific capacity in 1904 that it has in 1899.

The maximum velocity of the underflow detected during this investigation was 22.9 feet at Sherlock at a depth of 28 feet.

A noticeable feature of Arkansas River between Lakin and the eastern edge of Ford County is that it receives not a single tributary. The sand hills absorb all of the rainfall and deliver 60 per cent of it to the underflow, the rest disappearing as evaporation. Were the sands along the river finer and more compact it is quite probable that

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[1] The foregoing description of Arkansas River is largely abstracted from Water-Supply Paper U. S. Geol. Survey No. 173, 1906, pp. 19–20, and from Kansas Univ. Geol. Survey, vol. 2, pp. 17, 24–31.

[2] Water-Supply Paper U. S. Geol. Survey No. 153, 1906.

the river would receive tributaries at frequent intervals in its course from Lakin to Dodge.

Named in order downstream, the principal tributaries of Arkansas River that have all or a part of their basins in Kansas are:

Bear Creek.
White Woman Creek.
Pawnee Creek.
Walnut Creek.
Rattlesnake Creek.
Cow Creek.
Little Arkansas River.
Ninnescah River.
Slate Creek.
Walnut River.
Grouse Creek.
Salt Fork of Arkansas River.
Cimarron River.
Verdigris River.
Neosho River.

The discharge of the Arkansas at Coolidge, Syracuse, Dodge, Hutchinson, and Arkansas City is shown in Tables 140–144, inclusive.

TABLE 140.—*Mean monthly discharge of Arkansas River at Coolidge, Kans., for period May 7 to October 31, 1903.*

[Drainage area, 24,600 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| May | 319 | 8 | 57 |
| June | 28,720 | 17 | 6,608 |
| July | 1,320 | 5 | 211 |
| August | 1,470 | 1 | 122 |
| September | 2 | 0 | Trace. |
| October | 21 | 0 | 4 |
| The period | 28,720 | 0 | .......... |

TABLE 141.—*Mean monthly discharge of Arkansas River at Syracuse, Kans., for years 1903 and 1905, respectively, omitting December, 1905.*

[Drainage area, 25,000 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 500 | 3 | 124 |
| February | 1,660 | 95 | 551 |
| March | 1,545 | 40 | 375 |
| April | 24,800 | 10 | 1,930 |
| May | 16,300 | 20 | 2,210 |
| June | 28,300 | 20 | 4,340 |
| July | 4,900 | 28 | 515 |
| August | 14,500 | 20 | 972 |
| September | 1,480 | 8 | 206 |
| October | 130 | 8 | 39.1 |
| November | 295 | 8 | 83.5 |
| December | 28 | 8 | 17.0 |
| The period | 28,300 | 3 | 947 |

TABLE 142.—*Mean monthly discharge of Arkansas River, at Dodge, Kans., for period January 1 to December 31, 1904, March 1 to October 31, 1905.*

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 28 | 8 | 12.1 |
| February | 40 | 14 | 29.4 |
| March | 1,335 | 4 | 230 |
| April | 16,300 | 3 | 1,560 |
| May | 14,430 | 4 | 3,170 |
| June | 8,775 | 70 | 2,870 |
| July | 1,070 | 2 | 178 |
| August | 3,948 | 2 | 572 |
| September | 550 | 2 | 60 |
| October | 14,800 | 1 | 998 |
| November | 395 | 270 | 320 |
| December | 450 | 270 | 393 |
| The period | 16,300 | 1 | 866 |

TABLE 143.—*Mean monthly discharge of Arkansas River, at Hutchinson, Kans., for period May, 1895, to October, 1905.*

[Drainage area, 34,000 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 878 | 40 | 265 |
| February | 2,420 | 73 | 382 |
| March | 2,384 | 51 | 409 |
| April | 9,670 | 38 | 672 |
| May | 10,035 | 32 | 1,300 |
| June | 11,645 | 25 | 2,030 |
| July | 19,600 | 4 | 1,030 |
| August | 8,040 | 0 | 692 |
| September | 1,203 | 4 | 173 |
| October | 7,730 | 0 | 268 |
| November | 630 | 11 | 134 |
| December | 645 | 32 | 145 |
| The period | 19,600 | 0.00 | 625 |

TABLE 144.—*Mean monthly discharge of Arkansas River, at Arkansas City, Kans., for period October, 1902, to July, 1906, except January, February, November, and December, 1905; January to April, 1906.*

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 445 | 37 | 248 |
| February | 1,140 | 70 | 367 |
| March | 3,120 | 272 | 1,190 |
| April | 3,270 | 238 | 923 |
| May | 11,300 | 285 | 2,650 |
| June | 24,100 | 90 | 4,590 |
| July | 40,300 | 180 | 3,800 |
| August | 6,160 | 75 | 1,360 |
| September | 4,720 | 75 | 800 |
| October | 5,540 | 70 | 654 |
| November | 4,560 | 125 | 762 |
| December | 860 | 33 | 401 |
| The period | 40,300 | 33 | 1,480 |

## QUALITY OF WATER.

### TESTS OF ARKANSAS RIVER AND ITS TRIBUTARIES IN COLORADO.

The water of Arkansas River at Canon City, Colo., is shown by assays 1 and 2, Table 145, to have moderate temporary hardness and to carry high sulphates. In these two assays the bicarbonates exceed the sulphates.

The water at Pueblo is shown by assay 3, Table 145, and analyses 1 and 2, Table 146, to have low temporary and marked permanent hardness.

The water of Purgatory River at Trinidad, Colo., is shown by assays 4 to 14, Table 145, to be high in sulphates, low in chlorides, and to have moderate temporary hardness.

At Ordway, Colo. (analysis 3, Table 146), Arkansas River carries water of high permanent hardness. The water here would be laxative because the magnesium and sodium are high and the sulphates predominate in marked degree over the carbonates.

### MAIN RIVER IN KANSAS.

The United States Geological Survey maintained three daily sampling stations on Arkansas River in Kansas, and a number of tests of the quality of the water on the main stream and its tributaries at points to the east of the Colorado-Kansas State line were made. The changes in the character of the water, shown by the many analyses and assays, are most interesting. At Deerfield samples were collected and forwarded by the United States Reclamation Service from November 19, 1906, to November 16, 1907; at Great Bend samples were collected by M. L. Roseborough and S. M. Smith from November 26, 1906, to December, 1907; at Arkansas City samples were collected by A. L. Newman from December 7, 1906, to December 10, 1907.

A record of analyses of composite samples of water of Arkansas River at Deerfield is presented in Table 147. These samples cover a period of one year, but the record is incomplete. A glance at this table discloses two salient facts; first, that the water of the river at Deerfield is highly mineralized; second, that except in the analysis of sample February 10 to 19, the sulphates are much higher than the bicarbonates. It appears, further, that the river carries a variable quantity of chlorides, for in some of the analyses the chlorides are 39 parts per million and in others they rise to more than 100 parts. The water should be classed as sodic calcic saline.

The table shows also that the water of the river at Deerfield is laxative, for it contains high magnesium, sodium, and sulphates. The water is of moderate temporary hardness.

A very incomplete record of the turbidities of the daily samples collected at Deerfield is given in Table 148. The turbidity of the river varies enormously. On May 16 and 17, 1907, it was 3; on June 12, 1907, it was 24,000. Such readings are merely numerical statements of well-known facts, for although much of the time the river consists of mere threads of water trickling across its sandy bed, when the floods carry off the snows melting at its headwaters it becomes a swirling, muddy torrent. The coefficient of fineness, Table 147, is high most of the time, indicating that the matter in suspension is coarse; and the rapidity with which the river drops from very high to low turbidities points to the same conclusion. For some periods, however, as August 13–24, 1907, and November 19–December 2, 1907, the coefficient of fineness is low.

Tests of the water of Arkansas River at Dodge (assay 15, Table 145, and analysis 4, Table 146) show that here, as at Deerfield, the sulphates predominate over the bicarbonates and carbonates. The water is laxative, and has high permanent and moderate temporary hardness.

The analyses of composite samples collected at Great Bend are recorded in Table 149. The analyses cover a period of one year.

The water of Arkansas River at Great Bend is heavily mineralized, though somewhat less than it is at Deerfield. In fact, all of the mineral constituents except the chlorides are lower. Sulphates are present in large quantities and predominate over the bicarbonates, and therefore, as the magnesium and sodium are high, the water is laxative. The temporary hardness is not marked and the permanent hardness is great. The chlorides are somewhat high for a river water, averaging 27 parts per million more than at Deerfield. The increase in chlorides is usually caused by the flowing salt well near the mouth of Pawnee Creek at Larned. The water of the river is unsuitable for industrial use, but satisfactory for irrigation.

The daily turbidity, as indicated by the samples at Great Bend, Table 150, is subject to great fluctuations. For long periods it is less than 100 and during November, 1907, never rose above 50. In June, July, and August the river was very turbid indeed. The greatest turbidity, 86,400, was noted on July 31, 1907, and the lowest, 3, on February 8 and April 25, 1907. The observed turbidities accord with the known character of the stream.

Tests of Arkansas River water at Alden are recorded in assays 21 and 25, Table 145. Assay 21 shows the result of a test of the river water above the mouth of Rattlesnake Creek, and assay 22 of the river below it. On the same day a sample was collected from Rattlesnake Creek near its mouth, but, unfortunately, the sample was lost. At the West Alden Bridge the chief contribution of salt that Arkansas River has received in its course from Colorado is supplied by the flowing salt well at Larned, and the chlorides in the water at the bridge at the time the test was made were only 107. Between the West Alden Bridge and Alden Bridge Rattlesnake Creek enters, bearing water that is contaminated by salt from the Big Salt Marsh and the Little Salt Marsh of Stafford County, and at Alden Bridge the salt content of the river had increased to 1,056 parts per million. Through the courtesy of Dr. Marion Trueheart observations at Alden were repeated on November 8, 1908, with the result shown in assays 22, 24, and 26, Table 145. The streams were at higher stage than when the 1907 samples were collected; but the chlorides at the West Alden Bridge were only 80 parts per million. Near its mouth Rattlesnake Creek carried 933 parts per million, and the river at Alden Bridge contained 169 parts per million. Thus the influence of Rattlesnake Creek on the river is very marked. A test of Rattlesnake Creek at St. John, above the salt marshes, is recorded in assay 23, Table 145. Here the water of the creek is soft and is low in chlorides. The effect of the water of Rattlesnake Creek on the water of Arkansas River at Sterling (analysis 9, Table 146), is manifest in the high chlorides.

A test of the water of Arkansas River at Wichita, recorded in analysis 13, Table 146, indicates that at the time the sample was taken the water of the river at Wichita was very much less highly mineralized than was the water of the river at Great Bend (Table 149) at any time during the period of the collection of samples there.

A record of the analyses of composite samples of Arkansas River water at Arkansas City, taken from the Land & Power Co.'s canal at Arkansas City, appears in Table 151. The head of this canal is above the mouth of Walnut River and also above a low dam, which diverts water of the Arkansas—sometimes practically all of it—down the canal into Walnut River 3 miles above its mouth. Samples were collected from the canal because the water it carried was believed to be representative of that in the river and because it was possible, through the courtesy of the Land & Power Co., to obtain a collector on the canal. The collection of the daily samples was somewhat interrupted, but covers a period of one year.

The table shows that the water of Arkansas River at Arkansas City is very different from that at either Great Bend or Deerfield. It is still heavily mineralized, though the total dissolved solids run lower than in the composite samples at Great Bend (Table 149), which average less than those of the composite samples at Deerfield (Table 147).

The sulphates in the samples at Deerfield and Great Bend are higher than the bicarbonates; but at Arkansas City, if these constituents be considered in terms of their chemical equivalents, it will be found that the bicarbonates predominated over the sulphates in the analyses from January 12 to February 7, from January 18 to July 27, and from September 16 to November 14, while the sulphates were in excess of the bicarbonates in the analyses of December 7 to January 8, February 8 to 17, December 1 to 10, and in the analyses made in the period from July 28 to September 15.

It should be noted that at Deerfield the sulphates are very high, at Great Bend they are much lower, and at Arkansas City they are lower still. But perhaps the most marked change in the water of the river is the variation in the chlorides and sodium as the stream progresses through the State, and in the changed ratio of the sodium to the chlorine at Deerfield, Great Bend, and Arkansas City. At Deerfield the sodium is high and the chlorides low, the ratio of sodium to chlorine being about 3 to 1; at Great Bend the sodium is less and the chlorides more than at Deerfield, so that the ratio of sodium to chlorine is about 1.7 to 1. The reduction in the sodium is probably accomplished by waters relatively low in sodium that join the river between the two cities, while the increase in chlorides is brought about by the flowing salt well at Larned. At Arkansas City the river water is much higher in sodium that at Great Bend and somewhat higher than at Deerfield. The chlorides at Arkansas City are much higher than at either of the two other places, and the ratio of sodium to chlorine is 1 to 1.2. The increase in sodium and chlorides is accomplished by drainage from salt marshes on Rattlesnake Creek and by contamination resulting from the operations in the large salt works at Hutchinson.

The daily turbidity record of Arkansas River at Arkansas City (Table 152) is very much broken. The highest reading, 4,124, was recorded on August 20, and the lowest, 8, on April 20, 1907.

TABLE 145.—*Assays of water of Arkansas River and its tributaries in Colorado and Kansas west of R. 7 E.*

[Parts per million.]

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | 1904. | | | | | | | |
| 1 | Aug. 3 | Arkansas River at Canon City, Colo. | 0.5 | ....... | 110 | 66 | 18 | By R. I. Meeker. |
| 2 | Sept. 3 | .....do......... | ....... | ....... | 98 | 84 | 10 | Do. |
| 3 | Sept. 2 | Arkansas River at Pueblo, Colo. | ....... | ....... | 101 | 168 | 10 | Do. |
| | 1905. | | | | | | | |
| 4 | Oct. 3 | Purgatory River at Trinidad, Colo. | .0 | 0.0 | 273 | 116 | 6 | Turbidity 300, by R. I. Meeker and W. A. Lamb. |
| 5 | Oct. 5 | .....do......... | 1.0 | 13.0 | 207 | 124 | 11 | Turbidity 1,111, by R. I. Meeker and W. A. Lamb |
| 6 | Oct. 6 | .....do......... | Tr. | .0 | 308 | 90 | 14 | Turbidity 285, by R. I. Meeker and W. A. Lamb. |
| 7 | Oct. 7 | .....do......... | 1.0 | .0 | 246 | 103 | 9 | Turbidity 650, by R. I. Meeker and W. A. Lamb. |

TABLE 145.—*Assays of water of Arkansas River and its tributaries in Colorado and Kansas west of R. 7 E.*—Continued.

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$) | Sulphate ($SO_4$). | Chlorine (Cl) | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | | |
| 8 | Oct. 8 | Purgatory River at Trinidad, Colo. | Tr. | 0.0 | 234 | 96 | 9 | Turbidity 480, by R. I. Meeker and W. A. Lamb. |
| 9 | Oct. 9 | .....do | Tr. | .0 | 210 | 104 | 9 | Turbidity 750, by R. I. Meeker and W. A. Lamb. |
| 10 | Oct. 10 | .....do | Tr. | .0 | 272 | 98 | 11 | Turbidity 650, by R. I. Meeker and W. A. Lamb. |
| 11 | Oct. 11 | .....do | .0 | .0 | 260 | 101 | 9 | Turbidity 800, by R. I. Meeker and W. A. Lamb. |
| 12 | Oct. 12 | .....do | Tr. | .0 | 260 | 77 | 9 | Turbidity 950, by R. I. Meeker and W. A. Lamb. |
| 13 | Oct. 13 | .....do | Tr. | .0 | 246 | 96 | 9 | Turbidity 1,500, by R. I. Meeker and W. A. Lamb. |
| 14 | Oct. 14 | .....do | Tr. | .0 | 246 | 97 | 9 | Turbidity 900, by R. I. Meeker and W. A. Lamb. |
| | 1907. | | | | | | | |
| 15 | Nov. 20 | Arkansas River at Dodge. | .0 | .0 | 254 | 492 | 52 | |
| 16 | Dec. 6 | Buckner Creek at Jetmore. | Tr. | .0 | 236 | 62 | 24 | |
| 17 | Dec. 2 | Pawnee Creek above Ideal Steam Landing, Larned. | .0 | 11.0 | 279 | 62 | 36 | Above Frizell's flowing salt well. |
| 18 | ...do..... | Pawnee Creek at Main Street, Larned. | .0 | 11.0 | 275 | 61 | 72 | Below Frizell's flowing salt well. |
| 19 | Dec. 10 | Sunset Lake, Ness | .0 | .0 | 258 | 88 | 20 | A widening of North Branch of Walnut Creek. |
| 20 | Dec. 8 | Walnut Creek on Park Street and north of Atchison, Topeka & Santa Fe Ry., Great Bend. | Tr. | .0 | 329 | 115 | 90 | |
| 21 | Dec. 28 | Arkansas River at west bridge, Alden. | .0 | 12.0 | 207 | 383 | 170 | Above Salt Creek, collected by Dr. Marion Trueheart. |
| | 1908. | | | | | | | |
| 22 | Nov. 8 | .....do | .0 | .0 | 246 | 626 | 80 | Do. |
| | 1907. | | | | | | | |
| 23 | Dec. 3 | Rattlesnake Creek 1½ miles west of St. John. | .0 | 12.0 | 197 | *a* Tr. | 26 | |
| | 1908. | | | | | | | |
| 24 | Nov. 8 | Rattlesnake Creek 1 mile above mouth at Alden. | Tr. | 12.0 | 262 | 139 | 933 | Collected by Dr. Marion Trueheart. |
| | 1907. | | | | | | | |
| 25 | Dec. 28 | Arkansas River at bridge, Alden. | .0 | 12.0 | 269 | 157 | 1.056 | Below Salt Creek. |
| | 1908. | | | | | | | |
| 26 | Nov. 8 | .....do | .0 | .0 | 242 | 626 | 169 | Below Salt Creek, collected by Dr. Marion Trueheart. |
| | 1906. | | | | | | | |
| 27 | Nov. 18 | Cow Creek at first bridge west of Main Street, Hutchinson. | .0 | Tr. | 147 | 88 | 121 | |
| 28 | Nov. 16 | West Emma Creek west of Newton. | .0 | 12.0 | 260 | *a* Tr. | 14 | |
| 29 | ...do..... | East Emma Creek west of Newton. | .0 | .0 | 328 | *a* Tr. | 14 | |
| 30 | ...do..... | Sand Creek, Newton | .0 | .0 | 334 | 344 | 30 | |
| 31 | ...do..... | Little Arkansas River at Halstead. | .0 | Tr. | 307 | *a* Tr. | ...... | |
| | 1907. | | | | | | | |
| 32 | Jan. 19 | Little Arkansas River at Murdock Ave., Wichita. | .0 | .0 | 113 | 40 | 25 | In high stage. |
| 33 | ...do.... | Chisholm Creek at Douglass Street, Wichita. | .0 | .0 | 65 | 146 | 15 | In flood. |
| 34 | Nov. 7 | South Fork Ninnescah River at Main Street, Pratt. | Tr. | .0 | 174 | *a* Tr. | 30 | |
| 35 | Dec. 31 | Ninnescah River at Main Street Bridge, Kingman. | .0 | 12.0 | 200 | *a* Tr. | 289 | |

*a* Less than 35 parts per million.

TABLE 145.—*Assays of water of Arkansas River and its tributaries in Colorado and Kansas west of R. 7 E.*—Continued.

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$) | Sulphate ($SO_4$) | Chlorine (Cl) | Remarks |
|---|---|---|---|---|---|---|---|---|
| | 1907. | | | | | | | |
| 36 | May 16 | Ninnescah River at Atchison, Topeka & Santa Fe Ry. bridge, Belle Plaine. | .0 | 6.0 | 230 | 61 | 171 | |
| 37 | Jan. 15 | Slate Creek 1 mile west and 3½ miles north of Geuda Springs. | .0 | Tr. | 323 | 406 | 265 | |
| 38 | May 12 | East Branch Walnut River at Eldorado. | .0 | .0 | 232 | *a* Tr. | 10 | |
| 39 | ...do..... | West Branch Walnut River at Eldorado. | .0 | .0 | 216 | *a* Tr. | 10 | |
| 40 | May 13 | Whitewater River 500 yards above mouth of West Branch of Whitewater River at Towanda. | .0 | .0 | 254 | 173 | 20 | |
| 41 | ...do..... | West Whitewater River at Towanda. | .0 | .0 | 328 | 626 | 24 | |
| 42 | May 11 | Whitewater River at Atchison, Topeka & Santa Fe Ry. bridge, Augusta. | .0 | .0 | 227 | 222 | 14 | |
| 43 | ...do..... | Walnut River at Augusta | .0 | .0 | 219 | *a* Tr | 14 | |
| 44 | Jan. 17 | Dutch Creek at Winfield. | Tr. | .0 | 122 | *a* Tr. | 15 | In flood. Local name, Timber Creek. |
| 45 | Jan. 12 | Silver Creek 9 miles east of Arkansas City. | .0 | .0 | 345 | *a* Tr. | 10 | |
| 46 | ...do..... | Grouse Creek 7 miles east of Arkansas City. | .0 | .0 | 288 | *a* Tr. | 10 | |
| | | *Salt Fork of Arkansas River.* | | | | | | |
| | 1908. | | | | | | | |
| 47 | Jan. 4 | Big Mule Creek at Wilmore. | Tr. | .0 | 226 | *a* Tr. | 15 | |
| 48 | ...do..... | Medicine Lodge River above Elm Creek at Medicine Lodge. | Tr. | 12.0 | 218 | 382 | 67 | |
| 49 | ...do..... | Elm Creek above Medicine Lodge River at Medicine Lodge. | Tr. | 12.0 | 220 | *a* Tr. | 26 | |
| 50 | Jan. 7 | Fall Creek at Main Street Bridge, Caldwell. | .0 | 12.0 | 352 | 146 | 67 | |
| 51 | ...do..... | Bluff Creek at waterworks, Caldwell. | Tr. | 12.0 | 288 | 168 | 72 | |
| | | *Tributaries of Cimarron River.* | | | | | | |
| 52 | Jan. 2 | Bear Creek east of Ashland. | .0 | .0 | 142 | 327 | 30 | |
| 53 | Jan. 3 | Bluff Creek west of Protection. | .0 | 12.0 | 245 | 229 | 30 | |
| 54 | ...do..... | Kiowa Creek east of Protection. | .0 | 12.0 | 200 | *a* Tr. | 15 | A branch of Cavalry Creek. |
| 55 | ...do..... | Cavalry Creek east of Protection. | .0 | .0 | 231 | *a* Tr. | 15 | |

*a* Less than 35 parts per million.

TABLE 146.—*Analyses of water from Arkansas River.*

[Parts per million.]

| No. | Date. | Stream and place. | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$).[a] | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sept. 30, 1902 | Arkansas River at Pueblo, Colo | Atchison, Topeka & Santa Fe Ry | 15 | 12 | 81 | 21 | 47 | 92 | | 201 | 21 | | |
| 2 | Aug. 6, 1903 | do | Denver & Rio Grande R. R | 17 | 1.5 | 32 | 8 | 25 | 48 | | 60 | 12 | | |
| 3 | | Reservoir (supply comes from Arkansas River), city waterworks, Ordway, Colo. | Missouri Pacific Ry | 19 | 3.5 | 108 | 34 | 62 | 95 | | 349 | 15 | 41 | 727 |
| 4 | Nov. 18, 1898 | Arkansas River at Dodge | Atchison, Topeka & Santa Fe Ry | | | 70 | 64 | 78 | 88 | | 250 | 144 | 87 | 769 |
| 5 | Nov. 14, 1898 | Duck Creek, three-fourths mile east of spring at Dodge. | do | | | 64 | 18 | 16 | 141 | | 10 | 17 | 44 | 308 |
| 6 | Feb. 24, 1899 | No. 5, Pawnee Creek, 2½ miles west of Larned | do | | | 106 | 17 | 73 | 223 | | 69 | 36 | 39 | 570 |
| 7 | Oct. 30, 1902 | North Fork of Walnut Creek (pond) at Ness | do | 20 | 1.4 | 64 | 19 | 37 | 132 | | 63 | 24 | | |
| 8 | Dec. 8, 1907 | Walnut Creek, Great Bend | F. W. Bushong | 30 | .1 | 108 | 20 | 97 | .0 | 375 | 101 | 90 | | 610 |
| 9 | Mar. 5, 1908 | Arkansas River, Sterling | Archie J. Weith | 26 | .11 | 141 | 45 | 382 | .0 | 268 | 481 | 422 | | 1,649 |
| 10 | Mar. 8, 1901 | Cow Creek, Hutchinson | Kennicott Water Softener Co | 11 | | 80 | 16 | 163 | 114 | | 88 | 240 | | |
| 11 | | Pond, Geneseo | Missouri Pacific Ry | 10 | 1.4 | 17 | 1.7 | 7.3 | 25 | | 14 | 6.3 | 17 | 102 |
| 12 | Nov. 19, 1902 | Little Arkansas River at Little River | Atchison, Topeka & Santa Fe Ry | 23 | 1.7 | 108 | 25 | 14 | 209 | | 25 | 21 | | |
| 13 | Apr. 1, 1904 | Arkansas River at Wichita | Kennicott Water Softener Co | 19 | 2.7 | 68 | 12 | 40 | 117 | | 60 | 36 | | |
| 14 | Oct. 14, 1902 | Ninnescah River at Pratt | Atchison, Topeka & Santa Fe Ry | 20 | 1.2 | 63 | 7.8 | 45 | 84 | | 41 | 76 | | |
| 15 | July 22, 1897 | Ninnescah River at Belle Plaine | do | | | 72 | 15 | 197 | 110 | | 58 | 303 | 34 | |
| 16 | Jan. 9, 1908 | do | F. W. Bushong | 39 | .08 | 79 | 17 | 160 | .0 | 285 | 59 | 202 | | 670 |
| 17 | May 24, 1901 | Slate Creek, city waterworks of Wellington | Atchison, Topeka & Santa Fe Ry | | | 93 | 36 | 78 | 162 | | 142 | 79 | 101 | 690 |
| 18 | Jan. 20, 1902 | Slate Creek, Wellington | do | | | 116 | 38 | 97 | 201 | | 202 | 33 | 74 | 763 |
| 19 | Oct. 25, 1902 | do | do | 5.0 | 1.2 | 57 | 19 | 20 | 122 | | 24 | 24 | | |
| 20 | Sept. 27, 1902 | West Branch of Walnut River at De Graff | do | 13 | .8 | 52 | 5.4 | 29 | 116 | | 5.1 | 12 | | |
| 21 | Dec. 11, 1902 | West Whitewater River at Whitewater | Chicago, Rock Island & Pacific Ry | 52 | 13 | 413 | 83 | 51 | 207 | | 1,017 | 54 | | |
| 22 | Sept. , 1908 | do | do | | (b) | 289 | 66 | 46 | 99 | | 802 | 67 | | 1,379 |
| 23 | Feb. 5, 1900 | Walnut River at Winfield | Atchison, Topeka & Santa Fe Ry | | | 145 | 28 | 38 | 182 | | 226 | 10 | 188 | 823 |
| 24 | Nov. 7, 1902 | do | do | 28 | 1.8 | 30 | 5.3 | 8.9 | 53 | | 12 | 12 | | |
| 25 | | Walnut River at Winfield city waterworks | Missouri Pacific Ry | 7.5 | 1 | 78 | 20 | 29 | 64 | | 162 | 45 | 52 | 459 |
| 26 | Sept. 30, 1902 | Walnut River at South Winfield | Atchison, Topeka & Santa Fe Ry | 28 | .7 | 30 | 16 | 30 | 71 | | 76 | 6 | | |
| 27 | Feb. 13, 1899 | Walnut River at Arkansas City | do | | | 124 | 20 | 35 | 132 | | 205 | 25 | 354 | 895 |
| 28 | Apr. 17, 1900 | do | do | | | 74 | | 23 | 91 | | 65 | 9.3 | 89 | 354 |
| 29 | Apr. 16, 1901 | do | do | | | 68 | 13 | 9.4 | 94 | | 66 | 15 | 36 | 301 |
| 30 | Dec. 10, 1903 | do | do | 14 | | 120 | 17 | 16 | 186 | | 69 | 18 | 74 | 514 |
| 31 | Mar. 2, 1903 | do | do | 12 | | 94 | 20 | 12 | 134 | | 96 | 11 | 62 | 438 |
| 32 | Sept. 25, 1903 | Arkansas River at Arkansas City | do | 15 | | 75 | 11 | 9.9 | 112 | | 58 | 13 | 82 | 377 |
| 33 | Nov. 7, 1902 | Creek at Cambridge | do | 18 | .6 | 69 | 13 | 9.8 | 128 | | 14 | 12 | | |
| 34 | | Grouse Creek at Dexter | Missouri Pacific Ry | 14 | 3.4 | 54 | 12 | 6.6 | 108 | | 8.5 | 5.5 | 9.9 | 223 |
| 35 | Oct. 21, 1902 | Elm Creek (town supply) at Medicine Lodge | Atchison, Topeka & Santa Fe Ry | 26 | 2.7 | 32 | 8.3 | 27 | 63 | | 37 | 20 | | |

[a] Obtained by computation to ionic form; results originally stated as in hypothetical combinations.

[b] $SiO_2+Fe_2O_3+Al_2O_3$.

TABLE 146.—*Analyses of water from Arkansas River*—Continued.

[Parts per million.]

| No. | Date. | Stream and place. | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | May 24, 1901 | Pond at Rago | Atchison, Topeka & Santa Fe Ry | ...... | ...... | 57 | 16 | 26 | 78 | ...... | 76 | 31 | 39 | 320 |
| 37 | Oct. 21, 1902 | ....do | ....do | 22 | ...... | 41 | 14 | 16 | 72 | ...... | 51 | 15 | ...... | ...... |
| 38 | May 24, 1901 | Chikaskia River at Argonia | ....do | ...... | ...... | 53 | 7.9 | 42 | 96 | ...... | 40 | 38 | 22 | 301 |
| 39 | Oct. 15, 1902 | ....do | ....do | 18 | ...... | 55 | 13 | 44 | 102 | ...... | 57 | 32 | ...... | ...... |
| 40 | Oct. 14, 1902 | Bluff Creek at Anthony | ....do | 12 | 1.4 | 58 | 18 | 35 | 98 | ...... | 95 | 24 | ...... | ...... |
| 41 | Dec. 11, 1902 | ....do | Chicago, Rock Island & Pacific Ry | 21 | 2.4 | 71 | 25 | 61 | 152 | ...... | 83 | 44 | ...... | ...... |
| 42 | Sept. , 1908 | ....do | ....do | ...... | *a* 13 | 79 | 34 | 76 | 157 | ...... | 131 | 76 | ...... | 566 |

*a* $SiO_2+Fe_2O_3+Al_2O_3$.

TABLE 147.—*Analyses of water from Arkansas River near Deerfield, Kans.*

[Drainage area, 25,860 (estimated) square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Dec. 11 | Dec. 20 | 730 | 968 | 1.33 | 16 | 1.2 | 239 | 86 | 280 | 0.0 | 283 | 1,171 | 2.2 | 104 | 2,167 |
| Dec. 21 | Dec. 31 | 1,900 | 2,102 | 1.11 | 19 | 1.0 | 223 | 76 | 250 | .0 | 296 | 781 | 4.0 | 83 | 1,911 |
| 1907. | 1907. | | | | | | | | | | | | | | |
| Jan. 2 | Jan. 13 | 1,020 | 913 | .90 | 26 | 1.2 | 229 | 70 | 289 | .0 | 144 | 1,201 | 4.0 | 84 | 2,109 |
| Jan. 14 | Jan. 24 | 1,460 | 1,354 | .93 | 42 | 1.0 | 233 | 74 | 301 | .0 | 280 | 1,174 | 3.5 | 94 | 2,144 |
| Jan. 25 | Feb. 7 | 422 | 428 | 1.01 | 45 | 1.2 | 217 | 79 | 282 | .0 | 215 | 1,127 | 2.0 | 85 | 2,031 |
| Feb. 10 | Feb. 19 | 3,360 | 2,688 | .80 | 56 | .10 | 97 | 12 | 29 | .0 | 288 | 65 | 4.9 | 76 | 410 |
| Feb. 24 | Mar. 7 | 607 | 526 | .87 | 68 | .30 | 256 | 88 | 298 | .0 | 263 | 1,163 | 1.2 | 95 | 2,179 |
| Mar. 8 | Mar. 18 | 20 | 33 | 1.65 | 25 | .80 | 217 | 67 | 243 | .0 | 242 | 992 | .5 | 75 | 1,808 |
| Mar. 19 | Mar. 28 | 21 | 32 | 1.52 | 22 | 1.6 | 194 | 73 | 246 | .0 | 236 | 953 | 1.2 | 82 | 1,764 |
| Mar. 29 | Apr. 9 | 14 | 21 | 1.50 | 25 | 3.0 | 180 | 62 | 222 | *a* 7.0 | 241 | 855 | 3.5 | 75 | 1,640 |
| Apr. 10 | Apr. 25 | 12 | 29 | 2.42 | 20 | 1.4 | 156 | 71 | 198 | .0 | 245 | 818 | 3.5 | 78 | 1,580 |
| Apr. 26 | May 5 | 14 | 31 | 2.21 | 22 | 1.0 | 187 | 70 | 229 | .0 | 245 | 876 | 2.8 | 82 | 1,647 |
| May 6 | May 15 | 13 | 28 | 2.15 | 26 | 1.0 | 191 | 64 | 242 | .0 | 247 | 900 | 1.9 | 76 | 1,666 |
| May 16 | May 25 | 117 | 101 | .86 | 26 | 1.5 | 182 | 42 | 228 | .0 | 220 | 854 | 2.8 | 76 | 1,583 |
| May 26 | June 5 | 3,247 | 2,380 | .73 | 24 | 1.2 | 147 | 74 | 224 | .0 | 232 | 841 | 5.5 | 76 | 1,612 |
| June 6 | June 15 | 21,240 | 16,570 | .78 | 27 | 5 | 185 | 51 | 178 | .0 | 258 | 746 | 10 | 53 | 1,421 |
| June 16 | June 25 | 320 | 207 | .65 | 26 | 3.5 | 179 | 76 | 219 | .0 | 222 | 842 | .3 | 73 | 1,572 |
| June 27 | July 11 | 6,000 | 6,100 | 1.00 | 34 | 4 | 136 | 49 | 153 | .0 | 203 | 565 | 5 | 48 | 1,116 |
| July 12 | July 21 | 4,425 | 3,270 | .74 | 28 | 10 | 141 | 51 | 151 | .0 | 178 | 541 | 3.5 | 46 | 1,114 |
| July 22 | Aug. 1 | 26,200 | 18,477 | .71 | 27 | 3.5 | 157 | 51 | 146 | .0 | 210 | 568 | 5.5 | 42 | 1,132 |
| Aug. 2 | Aug. 12 | 15,620 | 9,702 | .62 | 32 | 5 | 167 | 47 | 144 | .0 | 190 | 600 | 6.5 | 39 | 1,156 |
| Aug. 13 | Aug. 24 | 296 | 158 | .53 | 23 | .8 | 178 | 62 | 194 | .0 | 220 | 759 | 1.2 | 62 | 1,402 |
| Aug. 25 | Oct. 16 | 21 | 24 | 1.14 | 30 | .04 | 169 | 65 | 195 | .0 | 200 | 751 | .9 | 64 | 1,371 |
| Oct. 17 | Nov. 2 | 46 | 47 | 1.02 | 22 | .24 | 227 | 68 | 209 | .0 | 210 | 756 | .8 | 66 | 1,418 |
| Nov. 3 | Nov. 16 | 116 | 85 | .73 | 16 | .14 | 155 | 37 | 186 | .0 | 190 | 725 | 1.1 | 67 | 1,346 |
| Nov. 19 | Dec. 2 | 100 | 64 | .64 | 19 | .12 | 189 | 55 | 258 | .0 | 245 | 840 | 1.2 | 74 | 1,552 |
| Mean.......... | | 3,359 | 2,551 | 1.09 | 29 | 1.9 | 186 | 62 | 215 | .0 | 231 | 826 | 3.2 | 72 | 1,571 |
| Per cent of anhydrous residue..... | | ....... | ....... | ...... | 1.9 | .2 | 12.3 | 4.1 | 14.2 | 7.6 | ...... | 54.7 | .2 | 4.8 | ...... |

*a* Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 11, 1906, to November 16, 1907, by F. W. Bushong; from November 19 to December 2, 1907, by Archie J. Weith.

TABLE 148.—*Turbidity of daily samples of Arkansas River at Deerfield, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | ...... | ...... | ...... | 1,464 | 13 | 10 | 8 | ...... | ...... | ...... | ...... | 10 | ...... |
| 2 | ...... | 465 | ...... | 378 | 15 | 32 | 21,000 | ...... | ...... | ...... | ...... | 15 | 60 |
| 3 | ...... | 360 | 412 | ...... | 10 | 30 | ...... | ...... | ...... | ...... | ...... | 16 | ...... |
| 4 | ...... | ...... | 120 | ...... | 18 | 12 | 8,415 | ...... | ...... | ...... | ...... | 10 | ...... |
| 5 | ...... | 2,100 | 95 | ...... | 3 | 14 | 3,000 | ...... | ...... | ...... | ...... | 18 | ...... |
| 6 | ...... | ...... | 200 | 50 | ...... | 12 | 732 | ...... | ...... | ...... | ...... | ...... | ...... |
| 7 | ...... | 1,520 | 966 | 30 | ...... | 24 | 732 | ...... | ...... | ...... | ...... | 8 | ...... |
| 8 | ...... | 760 | ...... | 32 | 24 | 9 | ...... | ...... | ...... | ...... | ...... | 5 | ...... |
| 9 | ...... | 825 | ...... | 32 | 14 | 7 | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 10 | ...... | 1,000 | 6,000 | 10 | 18 | 9 | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 11 | 1,000 | 1,363 | 5,300 | ...... | 18 | 9 | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 12 | 1,040 | 933 | 5,830 | 14 | ...... | 24 | 24,000 | ...... | ...... | ...... | 8 | 12 | ...... |
| 13 | 885 | 900 | 4,390 | 9 | 15 | 14 | 20,000 | ...... | 933 | ...... | 16 | 15 | ...... |
| 14 | 820 | 290 | 3,680 | 30 | 15 | 14 | 6,600 | ...... | 900 | ...... | 10 | 16 | ...... |
| 15 | 615 | 130 | 2,400 | 18 | ...... | 3 | 1,932 | ...... | 510 | ...... | 16 | 532 | ...... |
| 16 | 730 | 315 | 1,800 | 27 | 15 | 3 | 1,530 | ...... | 295 | ...... | 15 | 532 | ...... |
| 17 | 800 | 80 | 1,800 | 12 | ...... | 4 | 900 | ...... | 115 | ...... | 18 | ...... | ...... |
| 18 | 585 | 245 | 1,300 | 18 | ...... | 14 | 562 | 8,800 | 24 | ...... | 10 | ...... | ...... |
| 19 | 550 | ...... | 1,100 | 12 | 8 | 14 | 60 | 3,060 | 45 | ...... | 10 | 225 | ...... |
| 20 | 345 | 1,300 | ...... | 14 | ...... | 3 | 30 | 1,000 | 47 | ...... | 8 | 265 | ...... |
| 21 | 615 | 1,400 | ...... | 9 | 8 | 3 | 28 | 220 | 25 | ...... | ...... | 240 | ...... |
| 22 | 1,000 | 2,200 | ...... | 85 | 9 | 460 | 16 | 866 | 25 | ...... | ...... | 90 | ...... |
| 23 | 1,750 | 5,000 | ...... | 12 | 7 | 160 | 28 | 485 | 18 | ...... | ...... | 24 | ...... |
| 24 | 1,950 | 3,600 | 666 | 9 | 9 | 430 | 26 | 34 | 28 | ...... | ...... | ...... | ...... |
| 25 | 2,050 | 966 | 680 | 20 | 9 | 80 | 34 | 70 | 65 | ...... | ...... | 36 | ...... |
| 26 | 2,100 | ...... | 562 | 25 | 12 | 5 | ...... | ...... | ...... | ...... | ...... | 45 | ...... |
| 27 | 2,000 | ...... | 340 | 10 | 3 | 5 | 12 | ...... | 24 | ...... | ...... | 45 | ...... |
| 28 | 1,770 | 550 | 485 | 7 | 9 | 8 | 12 | ...... | 20 | ...... | 270 | 32 | ...... |
| 29 | 2,310 | 155 | ...... | 13 | 9 | 8 | 13 | ...... | 8 | ...... | 90 | ...... | ...... |
| 30 | 2,060 | 150 | ...... | 10 | 7 | 8 | 40 | ...... | ...... | ...... | 12 | 50 | ...... |
| 31 | 1,670 | 600 | ...... | 14 | ...... | 8 | ...... | ...... | ...... | ...... | 16 | ...... | ...... |
| Mean | 1,269 | 1,088 | 1,906 | 88 | 12 | 46 | 5,173 | 1,817 | 193 | ...... | 38 | 102 | ...... |

NOTE.—Average, June 8 to June 11, 39,606; June 27 to July 11, 6,000; July 12 to 17, 5,196; July 26 to 27, 22,392, August 2 to 12, 15,620. Turbidities over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

TABLE 149.—*Analyses of water from Arkansas River near Great Bend, Kans.*

[Drainage area, 34,600 (estimated) square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Nov. 26 | Dec. 5 | 210 | 166 | 0.79 | 2.3 | [a]0.8 | 99 | 24 | 124 | 0.0 | 208 | 377 | 2.8 | 52 | 793 |
| Dec. 6 | Dec. 15 | 58 | 35 | .60 | ..... | 1.2 | 139 | 16 | 158 | .0 | 245 | 557 | .9 | 69 | 1,135 |
| Dec. 16 | Dec. 27 | 28 | 18 | .64 | 24 | .6 | 163 | 40 | 132 | [b]6.7 | 281 | 508 | 2.7 | 98 | 1,330 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 28 | Jan. 7 | 1,330 | 957 | .72 | 27 | 1.2 | 177 | 49 | 173 | .0 | 295 | 612 | 4.6 | 90 | 1,336 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 8 | Jan. 20 | 494 | 357 | .72 | 27 | 4.0 | 173 | 45 | 174 | 3.6 | 266 | 651 | 2.5 | 92 | 1.355 |
| Jan. 21 | Jan. 31 | 163 | 129 | .79 | 50 | 2.0 | 153 | 56 | 199 | .0 | 187 | 719 | 1.1 | 93 | 1,385 |
| Feb. 1 | Feb. 13 | 770 | 1,050 | 1.36 | 21 | .40 | 157 | 42 | 157 | .0 | 266 | 535 | .6 | 78 | 1,131 |
| Feb. 14 | Feb. 24 | 3,730 | 2,323 | .62 | 76 | .30 | 192 | 54 | 227 | .0 | 264 | 859 | 2.3 | 77 | 1,654 |
| Feb. 25 | Mar. 4 | 499 | 315 | .63 | 83 | .30 | 187 | 45 | 49 | [b]2.8 | 259 | 696 | 1.5 | 85 | 1,495 |
| Mar. 8 | Mar. 17 | 340 | 220 | .65 | 56 | .52 | 327 | 48 | 195 | .0 | 243 | 652 | .7 | 88 | 1,304 |
| Mar. 19 | Mar. 28 | 51 | 62 | 1.22 | 18 | .8 | 148 | 43 | 191 | .0 | 228 | 608 | .2 | 104 | 1,264 |
| Mar. 29 | Apr. 8 | 19 | 26 | 1.37 | 22 | .9 | 148 | 34 | 191 | .0 | 219 | 565 | .2 | 121 | 1,230 |
| Apr. 9 | Apr. 18 | 15 | 12 | .80 | 18 | 3.3 | 149 | 36 | 196 | 8.0 | 230 | 536 | .7 | 128 | 1,218 |
| Apr. 19 | Apr. 30 | 15 | 14 | .93 | 12 | 1.0 | 132 | 41 | 181 | .0 | 230 | 506 | 1.1 | 134 | 1,179 |
| May 1 | May 11 | 44 | 47 | 1.07 | 17 | 2.5 | 162 | 7.2 | 190 | .0 | 225 | 624 | .6 | 106 | 1,265 |
| May 12 | May 21 | 20 | 19 | .95 | 20 | .6 | 155 | 33 | 191 | .0 | 210 | 574 | .6 | 121 | 1,239 |
| May 22 | June 8 | 15 | 11 | .73 | 16 | 1.2 | 147 | 41 | 186 | .0 | 218 | 518 | .6 | 133 | 1,168 |
| June 10 | June 19 | 19,200 | 10,283 | .54 | 49 | 3.2 | 164 | 50 | 211 | .0 | 245 | 671 | 7.0 | 125 | 1,400 |
| June 21 | June 30 | 2,736 | 1,932 | .71 | 26 | 2 | 113 | 36 | 135 | .0 | 178 | 407 | 3.5 | 76 | 902 |
| July 1 | July 10 | 9,480 | 5,686 | .60 | 30 | 1.5 | 137 | 47 | 192 | .0 | 235 | 522 | 3.5 | 127 | 1,169 |
| July 11 | July 20 | 14,530 | 4,250 | .29 | 31 | 4 | 96 | 32 | 117 | .0 | 178 | 347 | 6.0 | 49 | 756 |
| July 21 | July 31 | 14,160 | 11,766 | .83 | 26 | 3 | 117 | 46 | 152 | .0 | 225 | 464 | .9 | 87 | 972 |
| Aug. 1 | Aug. 11 | 18,720 | 15,770 | .84 | 29 | 2.0 | 145 | 40 | 120 | .0 | 192 | 487 | 7.5 | 32 | 960 |
| Aug. 12 | Aug. 22 | 20,000 | 6,177 | .31 | 32 | 1.8 | 147 | 41 | 138 | .0 | 193 | 490 | 4.5 | 40 | 968 |
| Aug. 23 | Sept. 3 | 315 | 295 | .94 | 31 | .20 | 142 | 46 | 158 | [b]5.0 | 205 | 511 | 1.5 | 84 | 1,079 |
| Sept. 4 | Sept. 16 | 40 | 30 | .75 | 29 | .05 | 135 | 44 | 171 | .0 | 210 | 502 | .7 | 122 | 1,109 |
| Sept. 17 | Sept. 28 | 16 | 5.2 | .32 | 30 | .08 | 124 | 44 | 171 | .0 | 230 | 461 | .5 | 125 | 1,033 |
| Sept. 30 | Oct. 9 | 168 | 129 | .77 | 12 | .06 | 115 | 34 | 180 | .0 | 200 | 391 | .5 | 108 | 913 |
| Oct. 10 | Oct. 20 | 38 | 16 | .42 | 21 | .12 | 135 | 44 | 179 | .0 | 223 | 437 | .5 | 140 | 1,061 |
| Oct. 21 | Oct. 31 | 26 | 9 | .35 | 20 | .11 | 142 | 43 | 137 | .0 | 217 | 450 | .6 | 130 | 1,069 |
| Nov. 1 | Nov. 10 | 22 | 1 | .04 | 20 | .26 | 145 | 42 | 168 | .0 | 238 | 476 | .5 | 124 | 1,107 |
| Nov. 11 | Nov. 21 | 28 | 6.0 | .21 | 17 | .20 | 153 | 42 | 170 | .0 | 255 | 474 | .6 | 128 | 1,120 |
| Nov. 22 | Dec. 7 | 38 | 3 | .08 | 20 | .11 | 105 | 43 | 195 | .0 | 242 | 502 | .6 | 114 | 1,128 |
| Mean........ | | 3,252 | 1,882 | .68 | 28 | 1.2 | 149 | 40 | 167 | .0 | 230 | 536 | 1.9 | 99 | 1,158 |
| Per cent of anhydrous residue.... | | ...... | ......... | ..... | 2.5 | .1 | 13.1 | 3.5 | 14.7 | 10.0 | ..... | 47.2 | .2 | 8.7 | ..... |

[a] Al=0.34. [b] Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from November 26, 1906, to November 21, 1907, by F. W. Bushong; from November 22 to December 7, 1907, by Archie J. Weith.

TABLE 150.—*Turbidity of daily samples of Arkansas River at Great Bend, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | 1906. | | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | ....... | 205 | 3,340 | 43 | 150 | 25 | 35 | 5 | 732 | 24,000 | 105 | 510 | 18 | 40 |
| 2 | ....... | 12 | 2,700 | 120 | 485 | 15 | 9 | 14 | 370 | 38,800 | 70 | 32 | 40 | 24 |
| 3 | ....... | 15 | 170 | 10 | 416 | 11 | 40 | 14 | 430 | ........ | 65 | 90 | 32 | 24 |
| 4 | ....... | 6 | 270 | 10 | 242 | 26 | ..... | 20 | 140 | ........ | 65 | 36 | 16 | 60 |
| 5 | ....... | 6 | 400 | ........ | ...... | 14 | 42 | 27 | 110 | ........ | 50 | 40 | 18 | 45 |
| 6 | ....... | 12 | 443 | 44 | 370 | 17 | 38 | 13 | 60 | ........ | 55 | 155 | 15 | 32 |
| 7 | ....... | 11 | 80 | 5 | 933 | 13 | 55 | ........ | 36 | ........ | 80 | 400 | 15 | 36 |
| 8 | ....... | 12 | 8 | 3 | 650 | 20 | 55 | 14 | 38 | ........ | ...... | 250 | 15 | ..... |
| 9 | ....... | 10 | 8 | ........ | 600 | 20 | 52 | ........ | 10,880 | ........ | 45 | 95 | 30 | ..... |
| 10 | ....... | 5 | 8 | 110 | 370 | 13 | 55 | 27 | 82,000 | ........ | 32 | 85 | 24 | ..... |
| 11 | ....... | 400 | 550 | 360 | 332 | 14 | 55 | 9 | 72,000 | ........ | 40 | 70 | 30 | ..... |
| 12 | ....... | 31 | 635 | ........ | 350 | 9 | 40 | 28 | 33,588 | ........ | 30 | 80 | 30 | ..... |
| 13 | ....... | 45 | 1,732 | 7,000 | 242 | 25 | 34 | 7 | 20,222 | ........ | 16 | 36 | 50 | ..... |
| 14 | ....... | 36 | 1,763 | 7,500 | 238 | 13 | 13 | 2,000 | 8,415 | ........ | 15 | 12 | 40 | ..... |
| 15 | ....... | 15 | 115 | 7,730 | 200 | 15 | 15 | 72,000 | 1,200 | ........ | ...... | 15 | ...... | ..... |
| 16 | ....... | 6 | 36 | 4,080 | 240 | 15 | 18 | 67,176 | 833 | ........ | 12 | 12 | 12 | ..... |
| 17 | ....... | 8 | ........ | 3,000 | 160 | 15 | 20 | 31,000 | 1,200 | ........ | ...... | 45 | 15 | ..... |
| 18 | ....... | ....... | ........ | 5,400 | ...... | 12 | 12 | 9,900 | 2,220 | ........ | ...... | 24 | 18 | ..... |
| 19 | ....... | 20, | ........ | ........ | 120 | 16 | 18 | 9,900 | ........ | ........ | ...... | 12 | 18 | ..... |
| 20 | ....... | 12 | 80 | ........ | 100 | 15 | 12 | ........ | ........ | ........ | ...... | 30 | 30 | ..... |
| 21 | ....... | 80 | 515 | 2,000 | 60 | 18 | 13 | 9,163 | ........ | ........ | ...... | 15 | 32 | ..... |
| 22 | ....... | 5 | 465 | 1,600 | 22 | 19 | 14 | 4,392 | ........ | ........ | ...... | 16 | 36 | ..... |
| 23 | ....... | ....... | 32 | 1,134 | 48 | ..... | 20 | 4,392 | 650 | ........ | ...... | 10 | 18 | ..... |
| 24 | ....... | 5 | 248 | 1,100 | 35 | ..... | 10 | 1,200 | 40 | ........ | ...... | 8 | 45 | ..... |
| 25 | ....... | 5 | ........ | ........ | 34 | 3 | 18 | 1,000 | 160 | ........ | ...... | 50 | 50 | ..... |
| 26 | 10 | 125 | 36 | 833 | 36 | 9 | ..... | 933 | 61 | ........ | ...... | 18 | 36 | ..... |
| 27 | 270 | 13 | 40 | 666 | 18 | 10 | 15 | 3,120 | ........ | ........ | ...... | ..... | 70 | ..... |
| 28 | 15 | 1,300 | 60 | 290 | 38 | 10 | ..... | 1,000 | 650 | 260 | ...... | 40 | 18 | ..... |
| 29 | 1,300 | 1,900 | 85 | ........ | 36 | 16 | ..... | 800 | 15,840 | 245 | ...... | 40 | ...... | ..... |
| 30 | 5 | ....... | 110 | ........ | 16 | 28 | 10 | 1,360 | 33,600 | 150 | 70 | 30 | 30 | ..... |
| 31 | ....... | 2,000 | 36 | ........ | ...... | ..... | 18 | ........ | 86,400 | 110 | ...... | 30 | ...... | ..... |
| Mean. | 320 | 225 | 517 | 1,956 | 234 | 11 | 27 | 8,130 | 14,303 | 10,594 | 50 | 76 | 29 | 37 |

NOTE.—Averages: July 19 to 20, 2,800; July 21 to 22, 1,840; August 1 to 11, 18,720; August 12 to 22, 20,000; August 23 to September 3, 315; September 17 to 28, 16. Turbidities over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

TABLE 151.—*Analyses of water from Arkansas River at Arkansas City,[a] Kans.*

[Drainage area, 44,500 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. Dec. 7 | 1907. Jan. 8 | 1,700 | 1,179 | 0.69 | 24 | 0.8 | 108 | 32 | 267 | 0.0 | 295 | 300 | 3.6 | 278 | 1,132 |
| 1907. Jan. 12 | Jan. 21 | 872 | 709 | .81 | 41 | 3.0 | 92 | 7.2 | 193 | .0 | 276 | 201 | 3.5 | 221 | 882 |
| Jan. 22 | Feb. 7 | 415 | 343 | .83 | 40 | .20 | 74 | 21 | 162 | [b]12 | 238 | 135 | 3.0 | 180 | 707 |
| Feb. 8 | Feb. 17 | 1,480 | 763 | .52 | 84 | .52 | 120 | 28 | 217 | .0 | 310 | 270 | 2.3 | 229 | 1,309 |
| Feb. 18 | Mar. 10 | 480 | 339 | .71 | 54 | .6 | 109 | 26 | 274 | .0 | 310 | 57 | 1.2 | 330 | 1,177 |
| Mar. 15 | Mar. 24 | 132 | 167 | 1.26 | 31 | 2.8 | 109 | 26 | 253 | [b]5.5 | 288 | 196 | 1.2 | 317 | 1,060 |
| Apr. 8 | Apr. 18 | 14 | 9 | .64 | 14 | 1.2 | 103 | 14 | 252 | .0 | 282 | 179 | .7 | 330 | 1,024 |
| Apr. 19 | Apr. 27 | 18 | 48 | 2.67 | 17 | 1.8 | 85 | 24 | 241 | .0 | 261 | 169 | 1.0 | 328 | 1,011 |
| Apr. 28 | May 7 | 70 | 158 | 2.26 | 15 | 3.0 | 88 | 19 | 216 | .0 | 255 | 147 | 2.0 | 264 | 857 |
| May 10 | May 19 | 180 | 202 | 1.12 | 34 | 2.5 | 88 | 13 | 233 | .0 | 252 | 165 | 1.8 | 292 | 938 |
| May 25 | June 3 | 30 | 93 | 3.10 | 19 | .7 | 86 | 25 | 236 | .0 | 254 | 162 | 1.1 | 312 | 960 |
| June 6 | June 15 | 42 | 105 | 2.50 | 35 | 2 | 83 | 29 | 250 | .0 | 240 | 159 | 1.5 | 292 | 987 |
| June 28 | July 7 | 885 | 722 | .82 | 42 | 6 | 76 | 21 | 241 | .0 | 235 | 126 | 2.5 | 280 | 862 |
| July 8 | July 17 | 112 | 162 | 1.45 | 43 | 1.5 | 86 | 24 | 262 | [b]12 | 230 | 152 | 1.0 | 328 | 995 |
| July 18 | July 27 | 3,000 | 2,224 | .74 | 39 | 12 | 64 | 19 | ...... | .0 | 223 | 100 | 2.8 | 192 | 662 |
| July 28 | Aug. 6 | 27,500 | 19,555 | .71 | 36 | 1.5 | 123 | 40 | 184 | .0 | 275 | 363 | 1.9 | 164 | 1,028 |
| Aug. 7 | Aug. 16 | 18,360 | 12,182 | .66 | 22 | 1.0 | 128 | 34 | 166 | .0 | 200 | 415 | 6.0 | 125 | 976 |
| Aug. 17 | Aug. 26 | 3,320 | 2,432 | .73 | 24 | .18 | 103 | 30 | 170 | .0 | 200 | 270 | 2.8 | 170 | 837 |
| Aug. 27 | Sept. 5 | 250 | 250 | 1.00 | 32 | .07 | 97 | 30 | 254 | .0 | 210 | 230 | 1.1 | 314 | 1,067 |
| Sept. 6 | Sept. 15 | 95 | 147 | 1.55 | 41 | .05 | 90 | 30 | 279 | .0 | 230 | 210 | .5 | 364 | 1,105 |
| Sept. 16 | Sept. 25 | 80 | 116 | 1.45 | 24 | .05 | 93 | 28 | 237 | .0 | 263 | 167 | 2.3 | 310 | 956 |
| Sept. 26 | Oct. 5 | 562 | 726 | 1.29 | 16 | .10 | 86 | 21 | 219 | .0 | 172 | 115 | 1.5 | 306 | 813 |
| Oct. 6 | Oct. 15 | 238 | 180 | .76 | 31 | .20 | 92 | 21 | 270 | .0 | 250 | 146 | 1.8 | 349 | 994 |
| Oct. 16 | Oct. 25 | 130 | 139 | 1.07 | 18 | .12 | 97 | 23 | 305 | .0 | 225 | 157 | .6 | 440 | 1,141 |
| Oct. 26 | Nov. 4 | 65 | 64 | .98 | 24 | .30 | 96 | 18 | 396 | .0 | 275 | 152 | .5 | 430 | 1,155 |
| Nov. 5 | Nov. 14 | 68 | 53 | .78 | 21 | .24 | 97 | 20 | 273 | .0 | 280 | 148 | .8 | 386 | 1,078 |
| Dec. 1 | Dec. 10 | 39 | 37 | .95 | 17 | 1.6 | 93 | 27 | 270 | .0 | 255 | 313 | .8 | 368 | 1,029 |
| Mean........ | | 2,227 | 1,596 | 1.19 | 31 | 1.6 | 95 | 24 | 243 | .0 | 253 | 193 | 1.8 | 292 | 990 |
| Per cent of anhydrous residue..... | | ....... | ....... | ...... | 3.1 | .2 | 9.4 | 2.4 | 24.1 | 12.4 | ..... | 19.2 | .2 | 29.0 | ...... |

[a] The sampling station was located on the canal of the Land & Power Co., the head of which is above the mouth of Walnut River.

[b] Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 7, 1906, to January 21, 1907, and from March 15 to December 10, 1907, by F. W. Bushong; from January 22 to March 10, 1907, by Archie J. Weith..

TABLE 152.—*Turbidity of daily samples from Arkansas River at Arkansas City, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, Director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | | | | 200 | | 20 | 40 | | | | | 80 | 45 |
| 2 | | | | 190 | | 22 | 50 | | | | | 60 | 50 |
| 3 | | 1,370 | | 190 | | 22 | 60 | | | | | 70 | 32 |
| 4 | | 1,370 | | 260 | | 140 | | | | | | 60 | 40 |
| 5 | | 1,330 | 28 | 242 | | 140 | | | | | | 70 | 36 |
| 6 | | | 36 | 265 | | 295 | 50 | | | | 220 | 50 | 40 |
| 7 | 1,940 | 1,370 | 36 | 240 | | | 50 | | | | 235 | 70 | 36 |
| 8 | 1,700 | 1,330 | 45 | 240 | 13 | | 20 | 200 | | | 230 | 60 | 40 |
| 9 | 1,870 | | 42 | 240 | 10 | 90 | 36 | 200 | | | 245 | 60 | 32 |
| 10 | 1,740 | | 40 | 240 | 10 | 90 | 24 | 80 | | | 225 | 65 | 40 |
| 11 | 1,700 | | 155 | | | 60 | 16 | 115 | | | 235 | 70 | |
| 12 | 1,268 | 565 | 5,350 | | 14 | 60 | 55 | 100 | | | 240 | 70 | |
| 13 | | 414 | 2,800 | | 14 | 650 | 75 | 80 | | | 240 | 80 | |
| 14 | | 443 | 2,910 | | 15 | 800 | 50 | 80 | | | 250 | 85 | |
| 15 | | 488 | 370 | 285 | 17 | 32 | 45 | 70 | | | 255 | | |
| 16 | | 400 | 2,700 | 240 | 14 | 36 | | 100 | | 80 | 125 | | |
| 17 | | 313 | 360 | 110 | 19 | 25 | | 90 | 3,500 | 60 | 130 | | |
| 18 | | 222 | 3,000 | 125 | 10 | 25 | | | 3,320 | 120 | 150 | | |
| 19 | | 1,920 | | 90 | 10 | 20 | | | 3,750 | | 140 | | |
| 20 | | 2,295 | | 105 | 8 | | | | 4,124 | 100 | 150 | | |
| 21 | | 1,660 | | 105 | 9 | | | | 3,500 | 80 | 130 | | |
| 22 | | 1,030 | | 110 | 15 | | | | 2,950 | 65 | 130 | | |
| 23 | | 1,000 | | 65 | 14 | | | 1,200 | 3,170 | 55 | 120 | | |
| 24 | | 732 | | 80 | 27 | | | 562 | 3,000 | 60 | 100 | | |
| 25 | | 520 | | | 25 | 15 | | 613 | 3,170 | 80 | 120 | | |
| 26 | | 490 | | | 20 | 15 | | 600 | 3,320 | | 65 | | |
| 27 | | 140 | | | 32 | 18 | | 320 | | | 80 | | |
| 28 | | 140 | | | 14 | 16 | | | | | 60 | | |
| 29 | | | | | 12 | 18 | | | | | 80 | | |
| 30 | | | | | 13 | 24 | | | | | 50 | | |
| 31 | | | | | | 18 | | | | | 50 | | |
| Mean | 1,703 | 888 | 1,276 | 181 | 15 | 110 | 44 | 294 | 3,380 | 78 | 156 | 68 | 39 |

NOTE.—Averages: June 28 to July 7, 885; July 18 to July 27, 3.000; July 28 to August 6, 27,500; August 7 to August 16, 18,360; August 27 to September 5, 250; September 6 to 15, 95; September 26 to October 5, 562. Turbidities over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

## Bear Creek.

Bear Creek,[1] which rises in southeastern Colorado, enters Kansas a little south of the middle of the western boundary of Stanton and about 30 miles south of Arkansas River. The creek flows northeastward across Stanton County and enters Grant County about 4 miles from the northwest corner of that county. In the western part of Stanton County it is a constantly flowing stream of clear water, but it soon sinks and through most of its course is dry, except in times of flood, which usually occur about twice a year. The channel is very deep and rather narrow, and when in flood the stream is absolutely impassable. High water usually lasts about three days. The creek flows about 15 miles across the northwestern corner of Grant County into Kearny County, terminating in what is known as "Sunk Well," in the southeastern edge of the sand hills, but floods extend the course of the river about 5 miles farther into the sand hills of Kearny County to a point within a short distance of

[1] William Easton Hutchinson, by letter.

Arkansas River. The banks of Bear Creek are higher than the surrounding country. So marked is this peculiarity that in some places the stream looks like an artificially constructed irrigation ditch. A slight, elongated depression extending through the sand hills in line with Clear Lake, southeast of Hartland, makes it possible to believe that on some occasions in the past the waters of the creek have extended quite to the river. It has been a popular belief that Clear Lake indicated an outlet of a subsurface flow of the waters of Bear Creek. Careful investigations, however, have proved that such is not the case, but that if the waters of Bear Creek reach the river at all they must join the eastward underflow soon after reaching the sand hills.[1]

### White Woman Creek.[2]

A stream similar in every respect to Bear Creek on the south of the river is White Woman Creek on the north. This creek rises in Cheyenne County, Colo., a few miles west of the Kansas-Colorado State line and flows eastward for about 75 miles. In places its channel is eroded to a depth of nearly 100 feet below the uplands, and a flood plain nearly a mile wide has been produced. Southeast of Scott City the valley of the stream becomes lost in the Modoc Basin. Like Bear Creek, the stream is dry throughout a greater portion of the year, but in times of flood it pours out its waters abundantly into Modoc Basin.

East of Garden is a depression, locally called Shallow Valley, which it is popularly believed extends northeastward and connects with White Woman Creek at the Modoc Basin. It is not known that levels have been run in this valley from Garden to Scott, but to one following this channel it appears to the eye like the old valley of White Woman Creek. Waters from this valley, however, do not reach Arkansas River in a direct underground flow, but join the eastward-moving underflow of the river.

### Pawnee Creek.[3]

#### DESCRIPTION.

Pawnee Creek rises in the northern part of Gray County and flows northeastward and then eastward to its junction with Arkansas River at Larned. Its drainage basin lies north and northeast of Dodge and south of Walnut Creek and comprises the southern part of Ness County, the eastern part of Finney County, all of Hodgeman County, the northern part of Ford County, and all of Pawnee County except that portion which drains directly into Arkansas River.

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[1] Water-Supply Paper U. S. Geol. Survey No. 153, 1906, pp. 18-21.

[2] The description of White Woman Creek is taken from Kansas Univ. Geol. Survey, vol. 2, pp. 33, 34.

[3] Kansas Univ. Geol. Survey, vol. 2, pp. 32-33.

It is a small stream, but has an unusually large number of tributaries which drain an area of 50 or 60 townships to the north of Dodge. Its upper branches rise in the Tertiary deposits, but soon cut their channels through it to the Benton group. Tapping the groundwater of the Tertiary they have a constant flow throughout the year. A marked peculiarity of Pawnee Creek is that its upper branches on the south reach to within a mile or two of Arkansas River. Sawlog Creek, Buckner Creek, and Pawnee Fork, the chief tributaries, have worn channels 50 to 100 feet deep and have valleys varying from half a mile to 1 mile in width.

The country occupied by Pawnee Creek in Pawnee and Edwards counties is a broad, almost level, sandy plain, with a gentle inclination to the east.

### QUALITY OF WATER.

Tests of the waters of Pawnee Creek and its tributaries are recorded in assays 16, 17, and 18, Table 145, and analyses 5 and 6, Table 146. The three assays show waters of moderate temporary hardness and high sulphates. The fact that the chlorides are higher in assay 18 than in assay 17 is evidence that the salt well at Larned contaminates Pawnee Creek. Analysis 5 shows a soft water and analysis 6 a slightly laxative water of moderate temporary and low permanent hardness.

## Walnut Creek.[1]

### DESCRIPTION.

Walnut Creek rises in Lane County, near Dighton, and flows eastward, through Ness and Rush counties, entering Arkansas River about 4 miles below Great Bend. Its drainage basin is about 25 miles wide, and comprises the major parts of Lane, Ness, and Rush counties, as well as the southeastern corner of Barton County.

The stream rises in the Tertiary deposits, but in Ness County it reaches the Niobrara formation, into which it and its tributaries have cut deep channels. In Rush County it passes over the Benton group and finally reaches the Dakota sandstone in Barton County.

The width of the valley of Walnut Creek is surprisingly great, nearly equaling that of Kansas River itself. The bluff lines are exceedingly variable and depend upon the character of the material in which the valley is cut. At the east end of the valley, in the Dakota sandstone area, the bluff lines are relatively gentle. In fact, the valleys of Walnut Creek and Arkansas River coalesce several miles above Great Bend, so that throughout at least 10 miles of its course the creek has no bluff lines, but simply flows in its little channel through the general valley to its confluence

[1] Kansas Univ. Geol. Survey, vol. 2, pp. 34–35.

with the river. In Rush and Ness counties, where the Benton is exposed, the valley is limited by bluffs that in many places reach a height of 75 to 100 feet. Where the several tributaries of Walnut Creek have cut their channels into Niobrara chalk, the valleys are narrow and bluff lines very abrupt.

The valley of Walnut Creek is largely filled with fluviatile material, from which the principal water supply of the region is derived.

#### QUALITY OF WATER.

Tests of the water of Walnut Creek and its tributaries are recorded in assays 19 and 20, Table 145, and analyses 7 and 8, Table 146. Assay 19 and analysis 7 are tests of a small pond on the North Fork of Walnut Creek, and together indicate a water that is slightly laxative, and has moderate temporary and slight permanent hardness. Assay 20 and analysis 8 are tests of samples of Walnut Creek taken at the same time and spot. Together they show a laxative water of marked temporary hardness.

### Rattlesnake Creek.

#### DESCRIPTION.

Rattlesnake Creek rises in the southeastern part of Ford County near Bucklin and flows a general northeasterly course to Alden in Rice County, where it enters Arkansas River. The stream drains the northern part of Kiowa County, a small part of Edwards and Pratt counties, and practically all of Stafford County.

Rattlesnake Creek has a fairly constant flow and throughout its course has eroded its channel in the Tertiary deposits.

In the northeast corner of Stafford County the creek flows by a salt marsh which, although it does not discharge directly into the creek, makes it very salt. In fact, locally, from the salt marsh to its mouth Rattlesnake Creek is known as Salt Creek.

#### QUALITY OF WATER.

A test of the water of Rattlesnake Creek far above the salt marshes of Stafford County (assay 23, Table 145, p. 279), shows a soft water; a test of the water below these salt marshes (assay 24, Table 145) indicates clearly by the high chlorides how the drainage from these marshes has changed the character of the water.

### Cow Creek.

#### DESCRIPTION.

Cow Creek rises in the eastern part of Barton County and follows a general southeasterly course to its junction with Arkansas River at Hutchinson. The stream is a small one and drains most of Rice County.

#### QUALITY OF WATER.

Tests of the water of Cow Creek at Hutchinson recorded in assay 27, Table 145, and analysis 10, Table 146, p. 281, show a water of moderate temporary and marked permanent hardness.

### Little Arkansas River.

#### DESCRIPTION.

Little Arkansas River rises in the northern part of Rice County and flows southeastward to its junction with the Arkansas near Wichita.

Its drainage basin comprises the southern part of McPherson County, the eastern part of Rice County, the southeastern corner of Reno County, all except the eastern part of Harvey County, and a portion of the northern part of Sedgwick County. In this area are the *Equus* beds which are described on pages 34–35.

#### QUALITY OF WATER.

Tests of the water of Little Arkansas River and of some of its tributaries are recorded by analysis 12, Table 146, and assays 28 to 32, Table 145.

The analysis shows that toward its head the river carries a calcic alkaline water of high temporary and low permanent hardness. The waters of West Emma and East Emma creeks are shown by assays 28 and 29 to have considerable temporary and little permanent hardness, West Emma Creek having the softer water. In contrast to the waters of these two creeks is that of Sand Creek (assay 30, Table 145), which has very great permanent hardness. The sulphates in Sand Creek are higher than the bicarbonates, which are not, however, low, and the chlorides are higher than in the waters of the Emma creeks. This striking difference in the quality of the water of Sand Creek and the two Emma creeks is explained by the fact that Sand Creek flows in that part of the Permian area which contains the gypsum beds, whereas West Emma and East Emma creeks flow in the *Equus* beds and thus escape heavy mineralization. At Halstead (assay 31, Table 145) Little Arkansas River carries water of decided temporary and little permanent hardness. A test of Little Arkansas River in high stage at Wichita is recorded in assay 32, which shows abnormally low carbonates, indicating in this case the presence of considerable rain water.

### Ninnescah River.

#### DESCRIPTION.

Ninnescah River rises in the western part of Pratt County and flows in a general southeasterly direction to its union with Arkansas River north of Oxford in Sumner County. The principal tributary of Ninnescah River is North Fork, which rises in the southeast corner of Stafford County, flows in a general southeasterly course, and joins the main stream in Sedgwick County southeast of Cheney.

The Ninnescah drains the southeastern part of Stafford County, the southern part of Reno County, the northeastern part of Pratt County, the northern part of Kingman County, the western part of Sedgwick County, and the northeastern part of Sumner County. In Stafford, Reno, Pratt, and the northwestern part of Kingman counties the course of the river and its tributaries lies in the Tertiary deposits, but elsewhere its channel is in the Permian.

#### QUALITY OF WATER.

Tests of the water of Ninnescah River at Pratt (assay 34, Table 145, and analysis 14, Table 146), indicate a soft water, as would be expected from the position of the channel in the Tertiary deposits, but the analysis shows somewhat higher sulphates and chlorides than are shown by the assay. At Kingman (assay 35, Table 145) the water of the Ninnescah continues soft, but the chlorides are much higher than at Pratt. They are believed to be derived from abandoned salt works near the city. Tests of the water near the mouth of the river at Belle Plaine (assay 36, Table 145, and analyses 15 and 16, Table 146), indicate greater temporary and permanent hardness than are indicated by tests at Kingman and Pratt. The higher sulphates in all probability are derived from the Permian shales. The chlorides appear to be somewhat less than at Kingman, possibly because the water is diluted by that of the North Fork.

No tests were made of the water of North Fork of Ninnescah River.

### Slate Creek.

#### DESCRIPTION.

Slate Creek is a small stream that rises in the northwestern corner of Sumner County and flows a general southeasterly course diagonally across the county, emptying into Arkansas River southwest of Tannehill and about 2 miles north of Geuda Springs. The course of the creek lies wholly within that part of the Permian in which the gypsiferous shales lie near the surface.

#### QUALITY OF WATER.

That the water of Slate Creek has become highly mineralized with calcium, magnesium, sodium, carbonates, and sulphates derived from the Permian shales is shown by analyses 17, 18, and 19, Table 146 (p. 281), which represent the composition of the creek water at Wellington. The water here is not particularly high in chlorides. A test of a sample taken north of Geuda Springs (assay 37, Table 145), indicates much higher chlorides and higher sulphates than are indicated by any of the tests of the water of this creek at Wellington. The chlorides are derived from salt springs in Valverdi Township that are tributary to the creek.

### Walnut River.

#### DESCRIPTION.

Walnut River drains an area about 2,020 square miles in extent, comprising the eastern edges of Harvey and Sedgwick counties and all but the eastern edges of Butler and Cowley counties. The river is formed in Eldorado, Butler County, by the union of its east and west branches and flows southward to its junction with Arkansas River at Arkansas City. From source to mouth, a distance of about 75 miles in a straight line, the river falls from an elevation of about 1,410 feet to 1,030 feet above sea level.

The basin consists of gently rolling pasture or cultivated land and adjoins the drainage basin of the Cottonwood on the north, the Verdigris on the east, and the main Arkansas on the west.

A little southwest of Augusta, Walnut River is joined from the west by Whitewater River, which rises in the northeastern part of Harvey County. At Towanda the Whitewater receives West Whitewater River, which is formed north of Whitewater by the confluence of East Branch and West Branch of West Whitewater River, two streams that rise in Walton Township in the northeastern part of Harvey County.

The eastern tributaries, heading in the Flint Hills, are more important than those from the west except Whitewater River. The river and the western tributaries of the Walnut head in the divide separating Walnut River from Little Arkansas and Arkansas rivers.

The estimated monthly discharge of Walnut River at Arkansas City is given in the following table:

TABLE 153.—*Monthly discharge of Walnut River at Arkansas City, Kans., for period October, 1902, to November, 1903.*

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 385 | 105 | 233 |
| February | 2,140 | 122 | 323 |
| March | 6,990 | 460 | 1,260 |
| April | 2,140 | 180 | 523 |
| May | 17,300 | 240 | 5,080 |
| June | 11,500 | 485 | 1,830 |
| July | 485 | 105 | 261 |
| August | 385 | 90 | 232 |
| September | 7,590 | 60 | 534 |
| October | 2,760 | 45 | 234 |
| November | 12,800 | 75 | 880 |
| December | 510 | 90 | 265 |
| The period | 17,300 | 45 | 971 |

## QUALITY OF WATER.

The United States Geological Survey maintained a daily sampling station on Walnut River at Winfield from December 2, 1906, to November 26, 1907. Samples were collected by the Winfield Roller Mill & Elevator Co., and the completeness of the record of analyses of the composite samples, Table 154, testifies to the fidelity with which the sampling was done. The analyses show that the waters are heavily mineralized, as might be expected from the fact that the course of the river lies entirely within the Permian deposits. The total dissolved solids are high, but they vary a good deal.

The water belongs to the calcic alkaline class and has high permanent and moderate temporary hardness. The sulphates are high in all the samples, but only the composite sample of November 6–16 indicates that they are present in sufficient quantity to make treatment difficult.

The observed variation in the amount of sulphates is to be accounted for by changes in relative amount of water from Whitewater River, carried by the Walnut, the Whitewater supplying most of the sulphates. The bicarbonates also are shown to vary in amount.

A record of the turbidity of the daily samples of Walnut River appears in Table 155. Of the 328 readings made, a little more than 65 per cent was less than 50 and somewhat over 10 per cent was 100 or more. Long periods of low turbidity occurred from December 6, 1906, to January 16, 1907, from January 26 to March 2, 1907, from March 4 to May 4, 1907, and from July 2 to November 26, 1907. The lowest turbidity, 5, was recorded on February 11, and the highest, 2,925, on January 19. The coefficient of fineness, Table 154, varies from 0.43 to 2.20. The fact that in six of the composite samples the coefficient of fineness is less than 0.65, indicates that for considerable periods the matter in suspension in the river water was so fine that it would pass through slow sand filters unless coagulant was applied to the water.

Tests of the water of Walnut River at Arkansas City (analyses 27 to 31, Table 146) show about the same amplitude of variation as is shown at Winfield. The calcium and sulphates are high and the carbonates moderate in amount.

Tests of samples of Walnut River taken at Winfield at widely separated intervals recorded in analyses 23, 24, and 25, Table 146, indicate considerable variation in the composition of the river water.

TABLE 154.—*Analyses of water from Walnut River at Winfield, Kans.*

[Drainage area 1,870 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate radicle ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Dec. 2 | Dec. 11 | 165 | 125 | 0.76 | 22 | 1.4 | 76 | 10 | 29 | 0 0 | 222 | 52 | 4.2 | 12 | 286 |
| Dec. 12 | Dec. 21 | 20 | 16 | .80 | 21 | .8 | 92 | 16 | 31 | .0 | 323 | 55 | 3.0 | 12 | 368 |
| Dec. 22 | Dec. 31 | 12 | 6 | 50 | 26 | .4 | 101 | 22 | 33 | .0 | 360 | 58 | 3.7 | 15 | 388 |
| 1907. | 1907. | | | | | | | | | | | | | | |
| Jan. 1 | Jan. 10 | 11 | 9 | .82 | 19 | .7 | 107 | 18 | 24 | .0 | 372 | 70 | 4.2 | 18 | 544 |
| Jan. 11 | Jan. 20 | 613 | 423 | .69 | 39 | 4.0 | 58 | 7.9 | 33 | *a* 9.6 | 230 | 47 | 7.0 | 14 | 316 |
| Jan. 21 | Jan. 30 | 270 | 249 | .92 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | .... |
| Jan. 31 | Feb. 11 | 11 | 12 | 1.09 | 21 | .8 | 98 | 7.6 | 28 | .0 | 366 | 68 | 6.2 | 12 | 387 |
| Feb. 12 | Feb. 22 | 8 | 10 | 1.25 | 72 | .24 | 121 | 21 | 46 | .0 | 410 | 89 | 4.8 | 17 | 547 |
| Feb. 23 | Mar. 4 | 54 | 51 | .94 | 57 | .18 | 82 | 17 | 33 | .0 | 330 | 86 | 4.4 | 16 | 415 |
| Mar. 5 | Mar. 14 | 49 | 42 | .86 | 27 | .40 | 86 | 15 | 33 | .0 | 256 | 71 | 2.5 | 8.4 | 367 |
| Mar. 15 | Mar. 24 | 44 | 31 | .70 | 15 | 2.4 | 92 | 19 | 25 | *a* 8.2 | 276 | 73 | 3.3 | 9.6 | 367 |
| Mar. 26 | Apr. 4 | 61 | 38 | .62 | 16 | 1.2 | 98 | 13 | 30 | .0 | 323 | 77 | 4.9 | 7.3 | 406 |
| Apr. 5 | Apr. 15 | 40 | 25 | .62 | 14 | 1.0 | 105 | 15 | 30 | .0 | 374 | 96 | .7 | 13 | 437 |
| Apr. 16 | Apr. 26 | 47 | 22 | .47 | 7.2 | .8 | 101 | 18 | 27 | .0 | 317 | 106 | 1.5 | 15 | 530 |
| Apr. 27 | May 7 | 297 | 302 | 1.02 | 13 | 3.0 | 88 | 8.2 | 33 | .0 | 275 | 86 | 4.2 | 15 | 371 |
| May 8 | May 18 | 201 | 182 | .90 | 21 | 3.0 | 78 | 3.7 | 23 | .0 | 247 | 59 | 4.5 | 9 | 306 |
| May 19 | May 30 | 63 | 49 | .78 | 20 | 1.2 | 99 | 14 | 31 | .0 | 345 | 73 | 6.0 | 14 | 400 |
| June 1 | June 10 | 58 | 42 | .72 | 17 | 1.2 | 111 | 23 | 31 | .0 | 367 | 97 | 6.7 | 15 | 452 |
| June 11 | June 22 | 130 | 141 | 1.08 | 20 | 1.4 | 77 | 19 | 33 | .0 | 295 | 87 | 5.3 | 16 | 375 |
| June 23 | July 5 | 142 | 99 | .70 | 29 | 3.0 | 68 | 19 | 28 | .0 | 235 | 60 | 6.5 | 10 | 316 |
| July 7 | July 17 | 56 | 45 | .80 | 30 | 1.2 | 76 | 16 | 36 | .0 | 282 | 50 | 7.5 | 11 | 331 |
| July 18 | July 29 | 28 | 22 | .78 | 28 | 2.0 | 74 | 21 | 34 | *a* 5.0 | 277 | 73 | 4.5 | 14 | 344 |
| July 30 | Aug. 8 | 20 | 44 | 2.20 | 20 | 1.0 | 77 | 28 | 33 | .0 | 216 | 93 | 2.8 | 15 | 357 |
| Aug. 9 | Aug. 22 | 29 | 53 | 1.83 | 19 | 3.2 | 97 | 24 | 43 | .0 | 270 | 73 | 2.7 | 12 | 361 |
| Aug. 24 | Sept. 2 | 42 | 31 | .74 | 19 | .18 | 80 | 20 | 31 | .0 | 243 | 91 | 4.0 | 17 | 340 |
| Sept. 3 | Sept. 15 | 20 | 20 | 1.00 | 22 | .06 | 97 | 25 | 35 | .0 | 240 | 144 | 2.5 | 18 | 445 |
| Sept. 16 | Sept. 28 | 25 | 37 | 1.48 | 13 | .14 | 78 | 29 | 38 | 0 | 178 | 137 | Tr. | 20 | 382 |
| Sept. 29 | Oct. 10 | 28 | 28 | 1.00 | 16 | .04 | 87 | 23 | 35 | .0 | 260 | 115 | 2.0 | 17 | 408 |
| Oct. 14 | Oct. 23 | 18 | 25 | 1.39 | 8.6 | .10 | 77 | 20 | 34 | .0 | 225 | 114 | Tr. | 16 | 364 |
| Oct. 24 | Nov. 5 | 26 | 14 | .54 | 21 | .16 | 106 | 26 | 33 | .0 | 288 | 141 | 1.8 | 21 | 478 |
| Nov. 6 | Nov. 16 | 28 | 12 | .43 | 16 | .20 | 112 | 23 | 38 | .0 | 300 | 175 | 1.8 | 29 | 539 |
| Nov. 17 | Nov. 26 | 24 | ..... | ...... | ...... | ...... | ...... | ...... | ..... | .0 | 315 | ...... | 2.2 | 23 | .... |
| Mean......... | | 82 | 71 | .92 | 23 | 1.2 | 90 | 18 | 32 | .0 | 292 | 87 | 3.7 | 15 | 398 |
| Per cent of anhydrous residue..... | | ..... | ..... | ...... | 5.4 | 2.8 | 21.2 | 4.3 | 7.5 | 33.9 | ...... | 20.5 | .9 | 3.5 | .... |

*a* Abnormal, computed as $HCO_3$ in the average.

NOTE.—Analyses from December 2, 1906, to February 11, 1907, and from March 15, to November 26, 1907, by F. W. Bushong; from February 22, to March 14, 1907, by Archie J. Weith.

TABLE 155.—*Turbidity of daily samples from Walnut River at Winfield, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
| 1 | ...... | 8 | 12 | 15 | 80 | 43 | 62 | 120 | 20 | 20 | 45 | 12 |
| 2 | 550 | 7 | 20 | 24 | 70 | 34 | 62 | 75 | 13 | 18 | 24 | 16 |
| 3 | 310 | 9 | 8 | 220 | 65 | 55 | 53 | 62 | 8 | 18 | 18 | 12 |
| 4 | 183 | 15 | 7 | 200 | 42 | 43 | 50 | 48 | 18 | 24 | 24 | 18 |
| 5 | 135 | 10 | 6 | 65 | 42 | 900 | 43 | 48 | 18 | ...... | 15 | 18 |
| 6 | 95 | 15 | 9 | 60 | 45 | 800 | 43 | ...... | 12 | 20 | 32 | 30 |
| 7 | 65 | 14 | 10 | 85 | 47 | 966 | 58 | 60 | 27 | 16 | 15 | ...... |
| 8 | 55 | 5 | 10 | 40 | 47 | 562 | 70 | 70 | 40 | 12 | 40 | 16 |
| 9 | 50 | 12 | 10 | 40 | ...... | ...... | 70 | 70 | 45 | 24 | 36 | 24 |
| 10 | 45 | 12 | ...... | 32 | 46 | 190 | 65 | 70 | 25 | 26 | 15 | 30 |
| 11 | 50 | 14 | 5 | 32 | 27 | 120 | 55 | 75 | ...... | 30 | ...... | 32 |
| 12 | 50 | 13 | 10 | 42 | 32 | 65 | ...... | 48 | 18 | 24 | ...... | 50 |
| 13 | 16 | 33 | 9 | 50 | 37 | 75 | 68 | 35 | ...... | 24 | ...... | 32 |
| 14 | 25 | 28 | 6 | 45 | 38 | 532 | 50 | ...... | 24 | 12 | 15 | 36 |
| 15 | 25 | 42 | 7 | 38 | 42 | 265 | ...... | 40 | 14 | 15 | ...... | 15 |
| 16 | 18 | 45 | 8 | 36 | 45 | 75 | 65 | 60 | ...... | 40 | 18 | 18 |
| 17 | 18 | 390 | 9 | 40 | 62 | 65 | 65 | 32 | 24 | 24 | 12 | 15 |
| 18 | 15 | 237 | 9 | 36 | 45 | 65 | 43 | 30 | 200 | 12 | 18 | 24 |
| 19 | 10 | 2,925 | 9 | 45 | 55 | 65 | 60 | 43 | 190 | 16 | 18 | 24 |
| 20 | 15 | 2,400 | 13 | 50 | 55 | 68 | 60 | 45 | ...... | 18 | 16 | 45 |
| 21 | 10 | 1,950 | ...... | 50 | ...... | 60 | 65 | 22 | 50 | 15 | 15 | ...... |
| 22 | 10 | 950 | 8 | 47 | 57 | 55 | 765 | 27 | 55 | 32 | 32 | ...... |
| 23 | 24 | 460 | 20 | 48 | 44 | ...... | 170 | ...... | ...... | 36 | 18 | ...... |
| 24 | 14 | 140 | 12 | 48 | 42 | 42 | 160 | 32 | 56 | 30 | 45 | ...... |
| 25 | 10 | 100 | 11 | ...... | 30 | 46 | ...... | ...... | 65 | 30 | 18 | 16 |
| 26 | 11 | 45 | 12 | 32 | 35 | 100 | 160 | 20 | 65 | 18 | 45 | 18 |
| 27 | 10 | 12 | 15 | 45 | 24 | 70 | ...... | 16 | 50 | 30 | 45 | ...... |
| 28 | 8 | 16 | 13 | 40 | 55 | 65 | 460 | 22 | 45 | 18 | ...... | ...... |
| 29 | 10 | 14 | ...... | 90 | ...... | ...... | ...... | 22 | 50 | 40 | ...... | ...... |
| 30 | 9 | 12 | ...... | 48 | 52 | 62 | 120 | 26 | 32 | ...... | 30 | ...... |
| 31 | 11 | 16 | ...... | 95 | ...... | ...... | ...... | 16 | 20 | ...... | 24 | ...... |
| Mean | 62 | 321 | 10 | 58 | 47 | 203 | 118 | 46 | 46 | 23 | 25 | 24 |

NOTE.—Turbidities over 50 were determined with a Jackson turbidimeter, and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

Tests of samples taken from the east and west branches of the Walnut (assays 38 and 39, Table 145, and analysis 20, Table 146) show that the waters of these two streams are of moderate hardness, that the bicarbonates predominate over the sulphates, which are low, and that the chlorides are low. At Augusta (assay 43, Table 145) the water of the Walnut is of about the same quality as that of the two branches at Eldorado.

A sample of water from Whitewater River about the mouth of West Branch of Whitewater River at Towanda shows high sulphates, moderate bicarbonates, and low chlorides. The high sulphates are derived from the gypsum deposit, 7½ miles southwest of Burns on Davis Creek,[1] a stream that joins the Whitewater near Potwin and that cuts through the gypsum at a place where the bed is about 9 feet thick.

Tests of the West Whitewater at Whitewater (analyses 21 and 22, Table 146) show that the water of the creek at this point is very high in calcium, magnesium, and sulphates; in fact, this creek at Whitewater furnished the hardest surface water that was encountered

[1] Kansas Univ. Geol. Survey, vol. 5, p. 67.

during the whole examination of the quality of waters in the State, except only the water of Turkey Creek in Dickinson County. The calcium and sulphates are derived from gypsum deposits. Below Whitewater West Whitewater River receives a run, known as Gypsum Creek, that heads northwest of Annely and flows through the city. At Annely gypsum of good quality occurs in the wells at a depth of 30 feet, and the rock outcrops on the creek just south of the city. Still farther down West Whitewater River receives another Gypsum Creek, which heads near McLain and flows southeastward, passing somewhat northeast of Furley, where there was a plaster mill which used gypsum rock found near by. At Towanda, above Whitewater River, the water of West Whitewater River (assay 41, Table 145), is very high in sulphates, but at the time the sample was taken it was not as high in sulphates as when the analyses were made at Whitewater. A test of the water of Whitewater River at Augusta (assay 42, Table 145), shows the water to be very hard.

It appears from all the assays and analyses that above Augusta the water of Walnut River is of very fair quality for boiler use, but that at Augusta it becomes impregnated with sulphates, calcium, and magnesium brought in by Whitewater River, whose water should be shunned for boiler use. The water of West Whitewater River is even more highly mineralized with calcium and sulphates than is that of Whitewater River itself.

A test of Dutch, or, as it is locally known, Timber Creek, at Winfield is recorded in assay 44, Table 145. The creek was in flood at the time the sample was collected for assay and the bicarbonates are therefore perhaps somewhat lower than they would be when the creek is in normal stage.

The tributaries that enter Walnut River from the east appear to carry somewhat softer water than those from the west, because the eastern tributaries do not drain areas including gypsum deposits.

### Grouse Creek.

Grouse Creek rises in the southeast corner of Butler County and flows diagonally across Cowley County, emptying into Arkansas River at the Kansas-Oklahoma State line southeast of Arkansas City.

Tests of the waters of Grouse Creek and its principal tributaries, recorded in assays 45 and 46, Table 145 (p. 280), and analyses 33 and 34, Table 146 (p. 281), indicate low permanent hardness and temporary hardness not so excessive but that it can be removed by chemical treatment if its removal is found advisable.

## Salt Fork of Arkansas River.[1]

### DESCRIPTION.

Salt Fork of Arkansas River is formed by the junction of Nesgatunga and Big Mule creeks in the southwestern part of Barber County near Aetna. The stream soon passes into Oklahoma, flows across the northern edge of the great salt plains, from which it acquires the saline character that suggested its name, and then continues to its junction with Arkansas River in Noble and Kay counties, Okla. The principal tributaries of Salt Fork in Kansas, in addition to Nesgatunga and Big Mule creeks, are Medicine Lodge and Chikaskia rivers.

### NESGATUNGA AND BIG MULE CREEKS.

#### DESCRIPTION.

Nesgatunga and Big Mule creeks drain the southern part of the Medicine Lodge gypsum area, and, together with the other tributaries of Salt Creek west of Medicine Lodge River, carry the run-off from gypsum-bearing strata. The divide between Medicine Lodge River and these tributaries of Salt Fork of Arkansas River is broad in Comanche County and rapidly narrows to the southeast in Barber County. The area drained by all these creeks consists of soft red shales covered by a heavy gypsum layer, which is soft but much firmer than the friable shales below. All conditions have been favorable for rapid erosion, and the streams have cut deep valleys separated by narrow divides which are carved into towers and buttes of red clays and shales supported by interlacing selenite layers. Many of the buttes rise 200 feet above the canyon and are capped by a bed of massive white gypsum, producing an impression like that made by the "badlands" of the Northwest.

Rain and frost have widened the upper portions of the stream valleys, giving them the characteristic V form. The hills are somewhat circular in outline and their lower portions are hidden under a mass of fan-shaped talus. The erosion is at first checked by the gypsum caps, but when these are cut through goes forward rapidly.

In this area many streams with steep slopes are dry much of the year, for the water runs very rapidly into the rivers or disappears in the soft sandy beds of the streams. Some of these streams bear such appropriate names as Sand Creek, Dry Creek, etc. After heavy rains, they become raging torrents of tumultuous sand and silt laden waters, that are impossible to ford, and are active agents of erosion. The whole region presents most rugged topography and a scenery very different from that which characterizes the State as a whole.

[1] Much of the description of Salt Fork of Arkansas River is taken from Kansas Univ. Geol. Survey, vol. 5, pp. 37-39, p. 357.

#### QUALITY OF WATER.

The water of Big Mule Creek at Wilmore, according to assay 47, Table 145, is of moderate temporary and little permanent hardness, which might be predicted from the fact that the course of the stream from its head to Wilmore is entirely within the Tertiary deposits. About 6 miles southeast of Wilmore, Big Mule Creek cuts down to the Permian and flows therein to its junction with Nesgatunga Creek, so that in the lower part of its course the water is probably highly mineralized.

### MEDICINE LODGE RIVER.

#### DESCRIPTION.

Medicine Lodge River rises in the southern part of Kiowa County, and takes a general southeasterly course, passing across Barber County and thence into Alfalfa County, Okla., where it joins the Salt Fork of the Arkansas.

The river and the small streams that enter it at and somewhat below Belvidere rise in an area of Tertiary deposits, but it soon passes across the rocks of the Comanche series and enters an area of Permian deposits, in which it continues throughout the rest of its course in Kansas.

The main stream, its northern tributaries as far down as Sun City, and its southern tributaries as far south as Medicine Lodge, drain the northern part of the southern or Medicine Lodge gypsum area. South of Medicine Lodge Elm Creek enters the river from the north. Through much of its course Elm Creek flows in Tertiary deposits, but it enters the Comanche series south of Sawyer, in Barber County, and within a short distance cuts down to the Permian deposits, in which it continues to its mouth. It is normally a clear stream of bright water, which drains an area free from gypsum, a most fortunate circumstance for Medicine Lodge, which, though situated in the gypsum area, is able to get from Elm Creek a supply of soft water. The creeks south of the river, Bear, Dog, Little Bear, Bitter, Cedar, and Walnut, flow northward in parallel courses, the uniformity of direction being a striking feature.

The discharge of Medicine Lodge River at Kiowa is given in the following table:

TABLE 156.—*Monthly discharge of Medicine Lodge River at Kiowa, Kans., for period May 6, 1895, to October 31, 1896.*

[Drainage area, 1,300 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 68 | 36 | 46.0 |
| February | 55 | 23 | 42.0 |
| March | 55 | 15 | 33.0 |
| April | 171 | 4 | 40.0 |
| May | 187 | 5 | 26.0 |
| June | 11,860 | 0 | 639 |
| July | 24,600 | 12 | 977 |
| August | 427 | 0 | 18.0 |
| September | 110 | 0 | 12.0 |
| October | 130 | 5 | 25.0 |
| November | 154 | 14 | 49.0 |
| December | 156 | 12 | 26.0 |
| The period | 24,600 | 0 | 161 |

## QUALITY OF WATER.

The United States Geological Survey maintained a daily sampling station on Medicine Lodge River at Kiowa from January 22, 1906, to September 14, 1907. R. L. Vandusen and Lou Bedwell were the collectors. Results of the analyses of composite samples taken at this point are recorded in Table 157. The tests show that the river water is very heavily mineralized and that the sulphates predominate over the bicarbonates. The amount of sulphates present in the river water and the ratio of sulphates to bicarbonates fluctuate continually. Probably two causes operate to produce the changes. In times of heavy rain, the water of the river is in all likelihood freshened and the ratio of sulphates to bicarbonates altered. Likewise, when the percentage of Elm Creek water in the river rises the ratio of sulphates to carbonates is decreased and vice versa. The analyses show high sodium, high chlorides, and more iron than is found in many Kansas streams. Assays 48 and 49, Table 145, indicate that the chlorides come from Medicine Lodge River rather than Elm Creek.

Because of its great permanent hardness and tendency to corrode, the water of the river is unsuitable for boiler use.

A record of the turbidity of the daily samples at Kiowa appears in Table 158. Of the 204 readings made, over 49 per cent were less than 50 and nearly 37 per cent 100 or more. There were long periods of high and long periods of low turbidity. Thus from January 23 to February 28 and from June 30 to August 7, the turbidity was high, whereas from March 29 to April 30, from June 2 to 29, and from August 18 to 28 it was low. The highest turbidity, 966, was recorded on July 25 and lowest, 3, on April 22.

A test of the water of Medicine Lodge River at Medicine Lodge (assay 48, Table 145) shows very high sulphates and moderately high bicarbonates, so that it has very high permanent and moderately high temporary hardness. The high sulphates are to be expected, as the river flows through the heart of the Medicine Lodge gypsum area.

Elm Creek, which enters the river at Medicine Lodge, has nowhere in its course eroded through gypsum deposits nor has it become highly mineralized in its rather short passage in the Permian deposits. On the contrary, it carries a very soft water, as is shown by assay 49, Table 145, and analysis 35, Table 146.

TABLE 157.—*Analyses of water from Medicine Lodge River, at Kiowa, Kans.*

[Drainage area, 940 square miles. Quantities in parts per million. Analyses made by F. W. Bushong in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1907. | 1907. | | | | | | | | | | | | | | |
| Jan. 21 | Feb. 1 | 152 | 164 | 1.08 | 39 | 1.8 | 218 | 47 | 90 | 0.0 | 280 | 512 | 3.5 | 84 | 1,266 |
| Feb. 2 | Feb. 12 | 162 | 171 | 1.06 | 26 | .20 | 192 | 37 | 105 | .0 | 288 | 495 | .6 | 92 | 1,081 |
| Feb. 13 | Feb. 23 | 134 | 116 | .86 | 87 | .40 | 177 | 36 | 94 | .0 | 266 | 443 | .7 | 69 | 1,048 |
| Feb. 24 | Mar. 26 | 115 | 182 | 1.58 | 24 | 2.0 | 164 | 36 | 89 | .0 | 230 | 428 | 1.2 | 74 | 953 |
| Mar. 27 | Apr. 5 | 49 | 70 | 1.43 | 18 | .6 | 152 | 44 | 104 | .0 | 203 | 457 | .3 | 100 | 1,014 |
| Apr. 6 | Apr. 15 | 41 | 79 | 1.93 | 27 | 3.0 | 148 | 30 | 86 | .0 | 222 | 376 | .6 | 75 | 880 |
| Apr. 16 | Apr. 26 | 24 | 35 | 1.46 | 20 | 1.8 | 151 | 40 | 115 | .0 | 309 | 343 | 28.0 | 98 | 1,072 |
| Apr. 27 | May 7 | 75 | 91 | 1.21 | 22 | 1.2 | 158 | 35 | 85 | .0 | 265 | 401 | 1.9 | 73 | 907 |
| May 8 | May 17 | 54 | 59 | 1.09 | 13 | .8 | 193 | 59 | 134 | .0 | 222 | 633 | 1.6 | 141 | 1,346 |
| May 18 | May 26 | 41 | 62 | 1.51 | 22 | 1.2 | 167 | 37 | 122 | .0 | 187 | 522 | 1.6 | 116 | 1,146 |
| May 28 | June 6 | 46 | 51 | 1.11 | 18 | .6 | 202 | 47 | 132 | .0 | 243 | 602 | 1.5 | 127 | 1,371 |
| June 7 | June 16 | 20 | 33 | 1.65 | 5.4 | .7 | 218 | 76 | 168 | .0 | 268 | 730 | 1.5 | 178 | 1,654 |
| June 17 | June 26 | 20 | 23 | 1.15 | 15 | 1.2 | 218 | 109 | 212 | .0 | 212 | 867 | 1.7 | 206 | 1,825 |
| June 27 | July 6 | 140 | 117 | .84 | 28 | 4.0 | 99 | 45 | 93 | .0 | 167 | 330 | 2.1 | 82 | 773 |
| July 7 | July 17 | 130 | 103 | .79 | 31 | 1.5 | 122 | 32 | 57 | .0 | 238 | 252 | 2.4 | 43 | 645 |
| July 18 | July 27 | 766 | 543 | .71 | 35 | 8.0 | 126 | 19 | 61 | .0 | 215 | 248 | 5.0 | 42 | 638 |
| July 28 | Aug. 9 | 296 | 214 | .72 | 30 | 2.2 | 98 | 19 | 46 | .0 | 150 | 215 | 3.0 | 30 | 506 |
| Aug. 10 | Aug. 19 | 67 | 83 | 1.24 | 32 | .8 | 152 | 43 | 103 | .0 | 213 | 423 | 3.5 | 94 | 958 |
| Aug. 20 | Aug. 30 | 40 | 29 | .72 | 27 | .50 | 168 | 62 | 133 | .0 | 225 | 510 | 6.0 | 132 | 1,176 |
| Aug. 31 | Sept. 11 | 62 | 58 | .94 | 16 | .09 | 132 | 34 | 92 | .0 | 185 | 316 | 3.5 | 111 | 815 |
| Sept. 12 | Sept. 14 | 36 | ..... | ...... | ..... | ...... | ..... | ..... | ...... | .0 | 170 | ...... | .4 | 91 | ...... |
| Mean........ | | 118 | 114 | 1.15 | 27 | 1.6 | 163 | 44 | 106 | .0 | 226 | 455 | 3.4 | 98 | 1,054 |
| Per cent of anhydrous residue.... | | ..... | ..... | ...... | 2.7 | .2 | 16.1 | 4.4 | 10.5 | 11.0 | ...... | 45.1 | .3 | 9.7 | ...... |

TABLE 158.—*Turbidity of daily samples from Medicine Lodge River at Kiowa, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | 1907. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. |
| 1 | ........ | 130 | ........ | 48 | ........ | ........ | 190 | ........ | 125 |
| 2 | ........ | 180 | ........ | 45 | 170 | 32 | 200 | 290 | 110 |
| 3 | ........ | 50 | ........ | 47 | 120 | 24 | 180 | 270 | 100 |
| 4 | ........ | 70 | ........ | 28 | 110 | 22 | 180 | ........ | 70 |
| 5 | ........ | 115 | ........ | 45 | 85 | 24 | 200 | ........ | 40 |
| 6 | ........ | 60 | ........ | 42 | 120 | 10 | 190 | 295 | 36 |
| 7 | ........ | 130 | ........ | 45 | 65 | 15 | 190 | 290 | 32 |
| 8 | ........ | 200 | ........ | 46 | 120 | 20 | 180 | 50 | 36 |
| 9 | ........ | ........ | ........ | 30 | 115 | 12 | 200 | 65 | 30 |
| 10 | ........ | 338 | ........ | 75 | 100 | 11 | 125 | 68 | 24 |
| 11 | ........ | 250 | ........ | 40 | 32 | 12 | 140 | 60 | 20 |
| 12 | ........ | 230 | ........ | 30 | 32 | 22 | 120 | 140 | 40 |
| 13 | ........ | 190 | ........ | 35 | 34 | 14 | 115 | 90 | 35 |
| 14 | ........ | 180 | ........ | 20 | 36 | 38 | 100 | 80 | 32 |
| 15 | ........ | ........ | ........ | 50 | 24 | 36 | 75 | 65 | ........ |
| 16 | ........ | 160 | ........ | 52 | 34 | 17 | ........ | 65 | ........ |
| 17 | ........ | 190 | ........ | 28 | 15 | 17 | 55 | 50 | ........ |
| 18 | ........ | 170 | ........ | 28 | 22 | 17 | 40 | 26 | ........ |
| 19 | ........ | 115 | ........ | 34 | 20 | 14 | 650 | 26 | ........ |
| 20 | ........ | 140 | ........ | 38 | 15 | 22 | 866 | 20 | ........ |
| 21 | ........ | 100 | ........ | 4 | 36 | 17 | 765 | 22 | ........ |
| 22 | ........ | 90 | 50 | 3 | 40 | 18 | 650 | 22 | ........ |
| 23 | 342 | 105 | 45 | ........ | 85 | 22 | 650 | 34 | ........ |
| 24 | 120 | 95 | 11 | 10 | 45 | 20 | 933 | 14 | ........ |
| 25 | 180 | 105 | 60 | 18 | 36 | 24 | 966 | 27 | ........ |
| 26 | 130 | 180 | 40 | 10 | 38 | 18 | 900 | 24 | ........ |
| 27 | ........ | 360 | 90 | 22 | 75 | 18 | 900 | 20 | ........ |
| 28 | 180 | 160 | 70 | 22 | 75 | 20 | 833 | 15 | ........ |
| 29 | 160 | ........ | 30 | 22 | 40 | 26 | 275 | 105 | ........ |
| 30 | 200 | ........ | 40 | 14 | 45 | 190 | 295 | 120 | ........ |
| 31 | 75 | ........ | 46 | ........ | 180 | ........ | 295 | 120 | ........ |
| Mean | 173 | 157 | 48 | 32 | 65 | 26 | 382 | 88 | 52 |

NOTE.—Turbidities of over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

## CHIKASKIA RIVER.

### DESCRIPTION.

Chikaskia River and its tributaries drain the southeastern part of Pratt County, the northeastern corner of Barber County, the southern part of Kingman County, the southwestern corner of Sumner County, and all of Harper County except the western part. In Barber, Pratt, and Kingman counties the river flows in the Tertiary deposits, but through the rest and greater part of its course the stream is within the Permian deposits.

### QUALITY OF WATER.

Through the courtesy of the Atchison, Topeka & Santa Fe Railway Co. daily samples of water were collected for the United States Geological Survey from Chikaskia River at Argonia from November 30, 1906, to July 5, 1907. A record of the analyses of the composite samples appears in Table 159.

The table shows a calcic alkaline water that is not highly mineralized, is low in chlorides, and that has low temporary and permanent hardness.

The turbidity of the daily samples is recorded in Table 160. Of the 201 readings, 89 per cent were less than 50, and somewhat more than 6 per cent were 100 or greater. The lowest turbidity, 3, was recorded on February 20 and the highest, 2,660, on January 19.

The coefficient of fineness (Table 159) is high, indicating that the matter in suspension is coarse.

The composition of the water of Bluff Creek which enters Chikaskia River southeast of Caldwell, is shown by analyses 40, 41, and 42, Table 146, and assay 51, Table 145. The tests indicate that the creek water varies in quality but that it has considerable temporary and marked permanent hardness. The water of Fall Creek, a tributary of Bluff Creek (assay 50, Table 145), appears to be similar to that of Bluff Creek, though it has somewhat more temporary hardness.

TABLE 159.—*Analyses of water from Chikaskia River at Argonia, Kans.*

[Drainage area, 520 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Nov. 30 | Dec. 10 | 60 | 39 | 0.65 | 31 | 0.30 | 51 | 11 | 36 | 0.0 | 278 | 26 | 0.2 | 14 | 299 |
| Dec. 11 | Dec. 23 | 12 | 13 | 1.08 | 21 | .9 | 71 | 14 | 40 | [a]5.0 | 304 | 37 | .8 | 19 | 325 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 24 | Jan. 3 | 12 | 16 | 1.33 | 29 | .40 | 69 | 15 | 43 | [a]4.8 | 302 | 35 | .9 | 19 | 315 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 4 | Jan. 13 | 13 | 17 | 1.31 | 25 | .8 | 68 | 22 | 39 | .0 | 300 | 34 | 4.0 | 20 | 307 |
| Jan. 14 | Jan. 24 | 417 | 261 | .62 | 43 | 2.0 | 56 | 6.2 | 46 | [a]9.6 | 260 | 25 | 3.3 | 11 | 310 |
| Jan. 25 | Feb. 5 | 35 | 36 | 1.03 | 46 | 1.6 | 72 | 6.5 | 41 | [a]15 | 284 | 45 | 1.9 | 15 | 354 |
| Feb. 7 | Feb. 16 | 30 | 43 | 1.43 | 35 | .18 | 71 | 16 | 35 | [a]6 | 262 | 41 | .4 | 13 | 350 |
| Feb. 18 | Feb. 27 | 17 | 13 | .76 | 48 | .20 | 74 | 16 | 47 | [a]4 | 280 | 62 | 1.2 | 15 | 383 |
| Feb. 28 | Mar. 10 | 25 | 29 | 1.16 | 32 | .32 | 65 | 16 | 43 | [a]4.8 | 275 | 34 | 1.2 | 15 | 323 |
| Mar. 11 | Mar. 21 | 14 | 15 | 1.07 | 17 | .25 | 64 | 12 | 27 | .0 | 281 | 38 | .5 | 14 | 306 |
| Mar. 22 | Mar. 31 | 16 | 15 | .94 | 19 | 1.8 | 60 | 10 | 39 | [a]8.9 | 262 | 29 | .3 | 13 | 297 |
| Apr. 1 | Apr. 10 | 15 | 11 | .73 | 20 | 1.0 | 68 | 4.3 | 36 | [a]6.2 | 263 | 40 | .2 | 12 | 305 |
| Apr. 11 | Apr. 21 | 12 | 10 | .83 | 14 | .8 | 63 | 3.5 | 33 | [a]4.0 | 264 | 34 | .4 | 15 | 282 |
| Apr. 22 | May 1 | 14 | 10 | .71 | 16 | 2.0 | 64 | 15 | 36 | .0 | 252 | 32 | .5 | 13 | 281 |
| May 2 | May 12 | 31 | 34 | 1.10 | 26 | 3.2 | 63 | 1.7 | 39 | .0 | 275 | 27 | .8 | 15 | 291 |
| May 13 | May 22 | 17 | 18 | 1.06 | 24 | 1.0 | 63 | 9 | 38 | .0 | 275 | 35 | .9 | 23 | 298 |
| May 24 | June 2 | 19 | 23 | 1.21 | 22 | .40 | 62 | 15 | 38 | .0 | 260 | 30 | .3 | 15 | 279 |
| June 3 | June 13 | 30 | 38 | 1.27 | 18 | .6 | 61 | 13 | 40 | [a]7.0 | 245 | 30 | .8 | 14 | 282 |
| June 14 | June 24 | 60 | 63 | 1.05 | 30 | 3.0 | 54 | 18 | 40 | [a]9.6 | 223 | 31 | 1.0 | 13 | 272 |
| June 25 | July 5 | 220 | 169 | .77 | 44 | 6.0 | 51 | 15 | 34 | .0 | 235 | 24 | 1.9 | 12 | 285 |
| Mean | | 53 | 44 | 1.00 | 28 | 1.3 | 64 | 12 | 38 | .0 | 278 | 34 | 1.1 | 15 | 307 |
| Per cent of anhydrous residue | | ..... | ..... | ...... | 8.5 | .6 | 19.3 | 3.6 | 11.5 | 41.4 | ..... | 10.3 | .3 | 4.5 | ...... |

[a] Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from November 30, 1906, to February 5, 1907, and from March 22 to July 5, 1907, by F. W. Bushong; from February 7 to March 21, 1907, by Archie J. Weith.

TABLE No. 160.—*Turbidity of daily samples from Chikaskia River at Argonia, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. |
| 1 | 120 | ........ | 34 | 35 | 14 | 24 | 30 | 100 |
| 2 | 70 | 27 | 43 | 35 | 20 | 9 | 30 | 80 |
| 3 | 45 | 14 | ........ | 24 | 14 | 20 | 22 | 60 |
| 4 | 27 | 7 | 18 | ........ | 12 | 34 | 14 | 78 |
| 5 | 18 | 7 | 10 | 24 | 14 | 34 | 27 | 80 |
| 6 | 18 | 8 | ........ | 16 | 13 | 75 | 30 | ........ |
| 7 | 16 | 11 | 15 | 16 | 15 | ........ | 26 | ........ |
| 8 | 11 | 6 | 7 | 20 | 14 | 35 | ........ | ........ |
| 9 | ........ | 10 | 45 | 13 | 15 | 24 | 32 | ........ |
| 10 | 12 | 6 | 48 | 22 | 15 | 24 | 40 | ........ |
| 11 | 12 | 13 | 40 | 15 | 13 | 28 | 38 | ........ |
| 12 | 12 | 45 | 32 | 20 | ........ | 30 | 38 | ........ |
| 13 | 12 | 20 | 35 | 15 | 10 | 26 | 35 | ........ |
| 14 | 10 | 24 | 24 | 12 | 13 | 18 | 43 | ........ |
| 15 | ........ | 18 | 30 | 12 | 13 | 10 | 27 | ........ |
| 16 | 10 | 16 | 25 | ........ | 12 | 15 | 6 | ........ |
| 17 | ........ | 18 | ........ | 24 | 13 | 5 | 22 | ........ |
| 18 | 15 | 16 | 26 | 10 | 9 | 15 | 28 | ........ |
| 19 | 12 | 2,660 | 16 | 12 | 11 | 20 | 28 | ........ |
| 20 | 10 | 1,000 | 3 | 12 | 13 | 15 | 24 | ........ |
| 21 | 8 | 225 | 5 | 12 | 11 | 27 | 36 | ........ |
| 22 | ........ | 120 | 20 | 10 | 13 | 20 | 320 | ........ |
| 23 | 13 | ........ | 24 | 18 | 10 | ........ | ........ | ........ |
| 24 | 12 | 70 | 15 | 18 | 5 | 15 | 70 | ........ |
| 25 | 8 | 40 | 12 | 18 | 9 | 15 | 110 | ........ |
| 26 | 10 | 40 | 26 | 22 | 15 | 18 | 425 | ........ |
| 27 | 6 | 36 | 23 | 18 | 18 | 14 | 765 | ........ |
| 28 | 7 | 36 | 40 | 18 | 3 | 14 | 260 | ........ |
| 29 | 10 | 30 | ........ | 13 | 9 | 5 | 130 | ........ |
| 30 | 19 | 42 | ........ | 14 | 32 | 15 | 110 | ........ |
| 31 | 6 | 24 | ........ | 12 | ........ | 30 | ........ | ........ |
| Mean | 20 | 158 | 25 | 18 | 13 | 25 | 99 | 80 |

NOTE.—Turbidities of over 50 were determined with a Jackson turbidimeter, and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

The results of tests of the water of a small pond tributary to Chikaskia River are given in analyses 36 and 37, Table 146. The water has high permanent and low temporary hardness. Tests of the river at Argonia are recorded in analyses 38 and 39, Table 146.

## Cimarron River.

### DESCRIPTION.

Cimarron River rises among the volcanic peaks in the Raton Mountains in Colfax County, N. Mex., at an elevation of nearly 7,000 feet above sea level, flows eastward to the eastern part of Cimarron County, Okla., where it turns to the northeast, passing across the southeastern corner of Baca County, Colo., and entering Kansas in the southwestern part of Morton County; at Ulysses, in Grant County, it turns sharply to the southeast, crossing Seward County and the southwestern corner of Meade County, and entering Oklahoma again a few miles beyond Miles, Kans., for about 25 miles it flows eastward across northern Beaver County, into Woodward County, Okla., then bends northeastward again, passing into Clark County, Kans., near the eastern edge of which it again turns abruptly to the southeast, passing for the third time into Oklahoma, across which it continues its southeastward course to its junction with the Arkansas at Keystone, Osage Nation, Okla. The extreme width of the basin is not more than 50 miles, its length is about 450 miles, and its area comprises 5,200 square miles.

As the river enters Oklahoma for the first time it flows nearly due east for more than 30 miles in a canyon cut in the sandstone plateau. Its valley averages 3 miles in width and the rugged hills, which disappear near the place where the river flows from Oklahoma into Colorado, are 300 to 400 feet high. From the sandstone issue springs which feed intermittent creeks. The channel in this part of its course is not more than 20 feet wide and is in many places confined by mud banks. From the canyon the river emerges onto the plain of Tertiary deposits, across which it flows in a broad shallow valley carved in the level upland. The banks become low, the channel widens, and the water wanders about over the sandy bed. At irregular intervals the river sinks into the sand and flows beneath the surface for a number of miles. For instance, from the old post office of Metcalf, Okla., to Point of Rocks, Kans., a distance of 25 miles, the channel of the Cimarron is often dry, but at Point of Rocks, Kans., the water comes to the surface at Wagon Bed Springs, a famous camp on the old Santa Fe trail, and the channel is usually full from that point on for a number of miles. It gradually sinks again before reaching Oklahoma a second time, so that above the mouth of Crooked Creek the channel is often dry.

In Kansas the bluffs on either side of the river are rounded rather than abrupt, but rise to a height of 100 to 150 feet. The valley itself averages not more than a mile in width throughout Morton, Stevens, and Grant counties. Farther east it widens so that in southwestern Meade County it is nearly 2 miles wide and the bluffs become more abrupt, owing to the "mortar beds" which lie near the surface throughout the greater part of Seward County. At Arkalon and a few miles above and below the city, the bluffs are particularly abrupt and the valley is entirely cut down to the broad, flat Tertiary plains. Perhaps no river valley in Kansas is more nearly a channel cut downward with almost vertical walls into a broad, flat plain. The mortar beds protect the surface from assuming the customary rounded forms of erosion. Up to this point, where the river enters Oklahoma for the third time, its water has been sweet, but in northern Woodward County, Okla., it flows through the Salt Plains and becomes so salty that stock will scarcely drink the water.

In Kansas, from Arkalon southward, Cimarron River usually has water in it throughout the greater part of the year. The stream is subject to a June rise, which is caused by the melting of snows in the mountains at its head.

Crooked, Sand, Bear, and Bluff Creeks, the principal tributaries of Cimarron River in Kansas, drain Clark County, the eastern part of Meade County, and the western part of Comanche County, and enter the main stream from the north. These streams rise in the Tertiary deposits and flow across a narrow strip of the Lower Cretaceous or Comanche series, and then complete their course in the Permian. In Meade and Clark counties the streams have relatively high velocity, and have cut channels from one-quarter to one-half a mile in width, covered to a depth of 10 to 20 feet with residual sands derived from the Tertiary. These streams present marked contrast to the streams that head in the Niobrara formation and the limestones and shales of the Benton group, and that have but little residual material in their beds, because the character of these rocks is such that the erosive processes consume almost everything worn loose.

Crooked Creek carries the drainage from the Meade artesian valley. From its head to Crooked L ranch, south of Meade, the bed of the stream is dry through much of the year, but below this point large springs insure a good flow.

William Easton Hutchinson states that Cimarron River is a constantly running stream throughout the entire width of Morton County, where it has a valley on one side or the other of the channel from one-half mile to three miles in width, on which an abundant crop of natural hay is raised. In Stevens County there is running water in Cimarron River at all seasons of the year. The approach to the stream in this county is greater than most streams of its size and is not cut through a level country, for breaks and hills extend a considerable distance from the stream in many places. In Grant County the river flows constantly and has a fine fertile valley on each side of the channel, that is sometimes covered by floods. When the overflow is at all regular large quantities of natural hay are produced in the valley.

In the southeastern corner of Grant County Cimarron River is joined by its North Fork, a stream which rises in Colorado, a short distance west of the Colorado-Kansas State line. Having its source in the plains, it is not affected by melting snows as is the Cimarron. In Morton County, the North Fork seldom carries any water, except in times of flood, which occur about twice a year. In the western part of Morton County, North Fork passes along on the level prairie with a steep bank and deep, narrow channel, but in the north-central part runs through a considerable draw. In Grant County North Fork receives drainage from a large rather shallow east and west draw in the northern part of Stanton County. This draw can hardly be called a stream, but it is connected in an indefinite way with the Fork. In Grant County North Fork is dry through perhaps one-half of its course most of the year, except in flood times. Through the greater part of the rest of its course, it carries running water, which here and there sinks beneath its bed to reappear again some miles farther on.

It has long been known that considerable quantities of ground water exist in the valley of the Cimarron east of the Colorado-Kansas State line, and the possibility of utilizing this water in rather extensive irrigation works has been seriously considered.

Under date of August 11, 1908, C. S. Slichter, of the United States Reclamation Service, made a report on the Cimarron project, Oklahoma, from which the following statements have been abstracted by Herman Stabler:

Preliminary investigations were begun in 1906 and were continued in 1907. The valley in Beaver and Woodward counties in Oklahoma and near Englewood in Kansas was found to be the only valley along the Cimarron between Englewood and the Colorado-Kansas State line of sufficient size to warrant operations by the Reclamation Service. This valley contains 14,600 acres of irrigable land on the the south side of the river in Oklahoma and 5,000 or 6,000 acres on the north side, mostly in Kansas. About half the area on the south side and 1,000 acres on the north side are now irrigated by means of works of unsatisfactory construction. Irrigation has been practiced in the valley for over 20 years and has been found profitable.

Much water sinks into the sand east of the narrows in sec. 32, T. 6 N., R. 28 E., Cimarron meridian. At least 40 second-feet sink in dry years, principally between the head of Hallock ditch and the mouth of Horse Creek. Borings disclose a subsurface material of irregular, complex deposits of sand and gravel. Five test wells show that in many places fine clay layers in the aquifers prevent a yield of pumped water sufficient for irrigation. Extensive tests would be required to locate the areas where wells would be successful.

The water of Cimarron River contains from 780 to 1,800 parts per million of dissolved solids, chiefly common salt. Long years of actual use have proved that under the conditions existing in the valley this water is not harmful to vegetation. Sixteen partial analyses indicate that the ground water of the valley is similar in quality to that of the river and show that in some places the ground water contains more and in others less dissolved solids than the water of the river. The water of three of the wells carried more than 4,000 parts per million of dissolved solids. A single test of the water of Horse Creek gave 420 parts per million of dissolved solids.

The report contains three recommendations—(1) that the existing irrigation works be improved and extended so that the natural flow of the river may be utilized more fully and with greater certainty; (2) that the river be gaged to determine the water supply; and (3) that plans for developing the ground water of the valley be suspended until operations of the residents shall have more fully established the areas where successful wells are possible.

## QUALITY OF WATER.

With the help of Col. C. D. Perry, of Claremont ranch, a daily sampling station was established by the United States Geological Survey on Cimarron River in Oklahoma, a little south of Englewood, Kans. Samples were collected by George Berends from November 30, 1906, to November 30, 1907.

The funds available for the present investigation were exhausted before the water resources of Stanton, Grant, Morton, and Stevens counties were investigated. These counties are very lightly populated. There are no large cities on Cimarron River and its tributaries in Kansas, above Liberal, in the southern part of Seward County.

The record of the analyses of the composite samples appears in Table 161. The table shows that the water of the river is at all times very heavily mineralized, and that the degree of mineralization varies a good deal from time to time.

The table shows that, if the constituents be considered in the terms of their chemical equivalents,[1] the sodium predominates to a marked degree over the calcium, which predominates over the magnesium. The chlorides predominate decidedly over the bicarbonates which, except in the analysis of June 11 to 20 and July 1 to 12, predominate over the sulphates. Considerable iron appears in some of the samples.

The water of Cimarron River is unsuitable for use in steam boilers, in which it would be likely to cause foaming and corrosion; for irrigation the water has long been used with satisfactory results. If drunk, the waters would prove laxative to those unaccustomed to it.

The record of the turbidity of the daily samples from Cimarron River, Table 162, is far from continuous. Of the 263 readings, over 20 per cent were less than 50, and over 63 per cent 100 or more. During the time observations were made, there occurred no period so long as ten days, during which the turbidity was less than 50. Most of the time the turbidity was considerably above 50, and from September 17 to November 30, the lowest turbidity reported was 90 and the next lowest 210. The lowest turbidity, 3, was noted on February 14, and the highest, 15,300, on September 17.

[1] See classification of waters, pp. 20–21.

The coefficient of fineness, Table 161, is generally high, but on July 1 to 12 it was 0.67, on October 23 to November 1, it was 0.66, November 4 to 13, it was 0.68, November 21 to 30, it was 0.68, and on July 13 to 22 it was only 0.44.

TABLE 161.—*Analyses of water from Cimarron River at Englewood, Kans.*

[Drainage area, 6,800 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate radicle ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Nov. 30 | Dec. 9 | 268 | 228 | 0.85 | 38 | 1.4 | 89 | 30 | 320 | a14 | 297 | 150 | 1.1 | 500 | 1,336 |
| Dec. 11 | Dec. 20 | 90 | 75 | .83 | 33 | .6 | 88 | 30 | 289 | a13 | 327 | 135 | 1.4 | 368 | 1,080 |
| Dec. 21 | Dec. 30 | 78 | 69 | .88 | 41 | 1.2 | 80 | 28 | 123 | a14 | 296 | 118 | .9 | 307 | 928 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 31 | Jan. 9 | 83 | 78 | .94 | 58 | 2.4 | 67 | 30 | 292 | a4.8 | 309 | 137 | 3.5 | 382 | 1,120 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 14 | Jan. 23 | 93 | 94 | 1.01 | 57 | 2.2 | 83 | 33 | 319 | a6.2 | 320 | 149 | .8 | 453 | 1,230 |
| Jan. 24 | Feb. 4 | 85 | 135 | 1.59 | 35 | .24 | 105 | 46 | 510 | .0 | 428 | 187 | 2.3 | 744 | 1,827 |
| Feb. 5 | Feb. 14 | 40 | 98 | 2.45 | 42 | .24 | 98 | 36 | 305 | .0 | 422 | 122 | 1.6 | 388 | 1,380 |
| Feb. 15 | Feb. 24 | 142 | 318 | 2.24 | 45 | .40 | 86 | 29 | 266 | a2.6 | 357 | 125 | 1.8 | 320 | 1,031 |
| Feb. 25 | Mar. 6 | 95 | 120 | 1.26 | 52 | .28 | 87 | 31 | 331 | a5.2 | 308 | 165 | .7 | 448 | 1,246 |
| Mar. 7 | Mar. 16 | 293 | 321 | 1.10 | 38 | .20 | 72 | 26 | 212 | .0 | 334 | 128 | .8 | 256 | 858 |
| Mar. 17 | Mar. 27 | 40 | 47 | 1.18 | 26 | 1.5 | 77 | 22 | 183 | a5.0 | 351 | 124 | .2 | 185 | 783 |
| Mar. 28 | Apr. 6 | 111 | 118 | 1.06 | 32 | 1.4 | 87 | 32 | 327 | .0 | 351 | 160 | .3 | 435 | 1,217 |
| Apr. 7 | Apr. 17 | 131 | 138 | 1.05 | 29 | 2.5 | 90 | 28 | 441 | .0 | 295 | 179 | 1.6 | 640 | 1,766 |
| Apr. 18 | Apr. 30 | 99 | 96 | .97 | 26 | 2.0 | 90 | 39 | 451 | .0 | 285 | 178 | .3 | 651 | 1,560 |
| May 1 | May 10 | 247 | 257 | 1.04 | 30 | 2.0 | 87 | 32 | 403 | .0 | 292 | 179 | 1.9 | 560 | 1,423 |
| May 11 | May 31 | 103 | 190 | 1.84 | 28 | 1.5 | 84 | 35 | 446 | .0 | 275 | 181 | 1.4 | 632 | 1,545 |
| June 11 | June 20 | 250 | 297 | 1.19 | 40 | 1.2 | 81 | 43 | 520 | a5.0 | 238 | 196 | 1.6 | 744 | 1,723 |
| June 21 | June 30 | 462 | 460 | .99 | 41 | 5 | 75 | 37 | 378 | a7.0 | 257 | 155 | .7 | 526 | 1,333 |
| July 1 | July 12 | 1,170 | 788 | .67 | 48 | 3.5 | 84 | 38 | 383 | a10 | 225 | 183 | 1.3 | 528 | 1,392 |
| July 13 | July 22 | 1,390 | 606 | .44 | 43 | 3 | 73 | 31 | 369 | a12 | 220 | 158 | .5 | 528 | 1,308 |
| July 23 | Aug. 1 | 785 | 684 | .87 | 29 | 1.5 | 79 | 35 | 332 | .0 | 263 | 149 | 7.0 | 472 | 1,208 |
| Aug. 2 | Aug. 12 | 3,680 | 2,661 | .72 | 40 | 3 | 75 | 28 | 235 | .0 | 270 | 115 | 4.7 | 314 | 942 |
| Aug. 13 | Aug. 24 | 1,350 | 940 | .70 | 40 | 1.5 | 90 | 38 | 359 | .0 | 315 | 151 | 3.0 | 500 | 1,317 |
| Aug. 25 | Sept. 9 | 240 | 235 | .98 | 34 | .09 | 84 | 40 | 438 | .0 | 280 | 182 | 1.4 | 622 | 1,537 |
| Sept. 10 | Sept. 20 | 9,700 | 6,743 | .70 | 24 | .20 | 91 | 46 | 411 | .0 | 285 | 189 | 1.1 | 568 | 1,425 |
| Sept. 21 | Oct. 8 | 1,920 | 1,426 | .74 | 39 | .36 | 85 | 40 | 424 | a7.0 | 255 | 177 | 2.7 | 618 | 1,498 |
| Oct. 13 | Oct. 22 | 316 | 220 | .70 | 28 | .30 | 94 | 38 | 389 | .0 | 290 | 160 | 1.0 | 550 | 1,389 |
| Oct. 23 | Nov. 1 | 470 | 308 | .66 | 39 | .25 | 89 | 33 | 379 | .0 | 289 | 155 | 1.3 | 520 | 1,373 |
| Nov. 4 | Nov. 13 | 283 | 193 | .68 | 37 | .30 | 95 | 38 | 400 | a3.0 | 295 | 147 | 1.5 | 582 | 1,452 |
| Nov. 21 | Nov. 30 | 328 | 222 | .68 | 33 | .16 | 90 | 37 | 440 | .0 | 292 | 171 | 2.5 | 616 | 1,503 |
| Mean | | 811 | 606 | 1.03 | 38 | 1.4 | 85 | 34 | 356 | .0 | 308 | 157 | 1.7 | 498 | 1,324 |
| Per cent of anhydrous residue | | ...... | ...... | ...... | 2.9 | .1 | 6.4 | 2.6 | 26.9 | 11.5 | ..... | 11.9 | .1 | 37.6 | ...... |

a Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from November 30, 1906, to January 23, 1907, and from March 17, to November 13, 1907, by F. W. Bushong; from January 24, to March 16, and from November 21, to 30, 1907, by Archie J. Weith.

TABLE 162.—*Turbidity of daily samples from Cimarron River at Englewood, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
| 1 | 350 | 50 | 200 | 140 | 155 | 140 | | | 60 | | 1,800 | 332 |
| 2 | 380 | 60 | 70 | 105 | 175 | 160 | | | 210 | | 1,650 | |
| 3 | 355 | 70 | 170 | 40 | 110 | 732 | | | | | 3,100 | |
| 4 | 330 | 65 | 18 | 90 | 140 | 325 | | | | | 2,500 | 290 |
| 5 | 268 | 55 | 50 | 12 | 140 | 140 | | | | | 1,900 | 285 |
| 6 | 155 | 70 | 45 | 95 | 200 | 317 | | | | | 1,200 | 260 |
| 7 | 90 | 140 | 100 | 390 | 100 | 160 | | | | | 600 | 270 |
| 8 | 100 | 130 | 60 | 385 | 140 | 170 | | | | | 650 | 210 |
| 9 | 120 | 175 | 120 | 1,866 | 40 | 170 | | 295 | | | | 310 |
| 10 | | | 5 | 9 | 390 | 160 | | 150 | | | | 310 |
| 11 | 190 | | 5 | 160 | 115 | 220 | 80 | 210 | | | | 350 |
| 12 | 80 | | 5 | 6 | 140 | 370 | 75 | 406 | | | | 280 |
| 13 | 90 | | 5 | 5 | 160 | 125 | 75 | | | | 220 | 270 |
| 14 | 95 | 160 | 3 | 10 | 75 | 150 | 60 | | | | 250 | |
| 15 | 95 | 70 | 732 | 10 | 85 | 180 | 75 | | | | 230 | |
| 16 | 85 | 40 | 45 | 85 | 95 | 85 | 70 | | | | 385 | |
| 17 | 105 | 70 | 125 | 8 | 100 | | 80 | | | 15,300 | 350 | |
| 18 | 90 | 100 | 110 | 8 | 75 | 65 | 580 | | 223 | | 350 | |
| 19 | 78 | 130 | 24 | 8 | 75 | 65 | 1,000 | 220 | 270 | 4,800 | | |
| 20 | 83 | 110 | 42 | 8 | 85 | 85 | 415 | 140 | 425 | | 90 | |
| 21 | 85 | 65 | 34 | 62 | | | 200 | 190 | 317 | 2,400 | 500 | 355 |
| 22 | 135 | 120 | 200 | 105 | 110 | | 45 | 160 | 765 | 2,200 | 473 | 340 |
| 23 | 105 | 60 | 50 | 18 | 115 | | 34 | 150 | 900 | 2,050 | 412 | 355 |
| 24 | 145 | 27 | 60 | | | 65 | 125 | 150 | 732 | 1,700 | 270 | 360 |
| 25 | 95 | 8 | 90 | 150 | 110 | | 115 | 125 | | 1,800 | 600 | 290 |
| 26 | 55 | 5 | 120 | 7 | 105 | | 115 | 125 | | 1,750 | | 340 |
| 27 | 37 | | 130 | 22 | 100 | | 680 | 2,800 | | | 833 | 370 |
| 28 | 58 | 55 | 130 | 8 | 65 | | 613 | 295 | | | 485 | 295 |
| 29 | 12 | 210 | | 13 | 75 | | 1,932 | 866 | | 3,100 | 390 | 285 |
| 30 | 75 | 85 | | 12 | 160 | | 765 | 200 | | 3,320 | 550 | 285 |
| 31 | 19 | | | 160 | | | | 5,598 | | | 360 | |
| Mean | 132 | 85 | 98 | 133 | 123 | 194 | 357 | 710 | 434 | 3,842 | 806 | 322 |

NOTE.—May averages: May 22 to 31, 95. July averages: July 1 to 8, 1,740; July 12 to 18, 1,100. August averages: August 2 to 12, 3,680; August 13 to 24, 1,350; August 25 to September 9, 240. September averages: September 10 to 20, 9,700. Turbidities over 50 were determined with a Jackson turbidimeter, and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

A test of the water of Bear Creek east of Ashland (assay 52, Table 145, p. 280), indicates that the water has high permanent and low temporary hardness. The water of Bluff Creek (assay 53, Table 145) appears to be of a similar character. The courses of these two streams for the most part lie in the Permian, so their waters would naturally dissolve sulphates from the rocks of this series.

Cavalry Creek and its tributary, Kiowa Creek, assays 55, 54, Table 145, at the point they were sampled derive most of their water from the Tertiary deposits; consequently the waters of these two streams have low permanent hardness, and the temporary hardness is also low. The fact that the chlorides are lower in the waters of Kiowa and Cavalry creeks than in those of Bluff and Bear creeks is significant, for the waters of the Tertiary are normally low in chlorides, whereas those of the Permian are apt to carry them in considerable quantity. Analyses of Cimarron River above and below the salt plains, and also analyses of several Oklahoma tributaries of the river are given in Water-Supply Paper 148, pages 150 and 151.

### Verdigris River.

#### DESCRIPTION.

Verdigris River drains an area 180 miles long and 72 miles in greatest width and comprising 8,610 square miles. The Flint Hills, in the northern part of its boundary, have an elevation of about 1,600 feet. The northern boundary varies in height from 1,200 to 1,400 feet; the eastern boundary falls from about 1,400 to 650 feet and the western boundary from 1,600 to 650 feet, decreasing from the north toward the south. The upper part of the area is comparatively rough, the general fall toward the river being about 25 feet to the mile. This portion of the basin is used for grazing purposes; the rest of the drainage area contains some of the best farming land in the Mississippi Valley.

In some places the general surface is broken by mounds rising 100 to 250 feet above the general level; such is Table Mound, 6 miles northwest of Independence, and the mounds near Fredonia and Cherrydale, Kans., and near Sequoia, Okla.

The river rises in the southeastern part of Chase County, Kans., and takes a general southeasterly course to a point a little below Coffeyville, where it passes into Oklahoma and discharges into Arkansas River a little above the mouth of Neosho River, in the northeastern part of Muskogee County. It is 290 miles long and falls from an elevation of 1,400 feet at its source to 700 feet at a point about 11 miles north of the Kansas and Oklahoma line, a distance of 141 miles. From this point to the mouth (148 miles) it falls about 100 feet. Throughout its length the river occupies a well-defined channel, with banks from 10 to 40 feet in height. The width at ordinary stage of water at the State line is 140 feet and at the mouth 250 feet. It is essentially a surface run-off stream; its water is muddy, its flood-flow large, summer flow small, and its surface fluctuations are large and rapid. Although it flows in a comparatively deep and well-defined channel, its banks are subject to overflow during floods, on account of the sluggish flow due to small fall and crooked channel. The bed and banks are composed of firm material that changes very little from year to year. Floods are common on Verdigris River. Rarely a year passes without a flood that causes overflow of some of the bottom lands along the river. There were five floods on this river from April 26 to July 10, 1904, that reached a stage of more than 27 feet above low water at Independence, and two of these reached a stage of more than 41 feet above low water.

The estimated monthly discharge of Verdigris River at Liberty, Kans., from 1896 to 1903 is shown in the following table:

TABLE 163.—*Mean monthly discharge of Verdigris River at Liberty, Kans., for period beginning January 1, 1896, and ending November 30, 1903.*

[Drainage area, 3,070 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 1,616 | 9 | 412 |
| February | 21,020 | 39 | 875 |
| March | 17,800 | 52 | 1,450 |
| April | 26,100 | 140 | 1,680 |
| May | 41,450 | 90 | 4,070 |
| June | 23,018 | 40 | 2,710 |
| July | 28,876 | 3 | 1,420 |
| August | 7,285 | 2 | 471 |
| September | 37,000 | 2 | 1,620 |
| October | 35,075 | 5 | 760 |
| November | 25,430 | 2 | 1,000 |
| December | 10,942 | 2 | 955 |
| The period | 41,450 | 2.00 | 1,450 |

The headwaters of the Verdigris, as well as those of its principal tributaries, Fall River, Elk River, and Caney River, are in the Flint Hills.

In Kansas, the entire Verdigris basin[1] lies within the Pennsylvanian series. The river has cut its channel through the "Garnett," Iola, and "Independence" limestones, and has reached base level almost to its source. The elevation of the "Independence" limestone is but little above the base level of the river at Independence, so that the river valley practically reached to the surface of the "Independence" limestone, producing conditions similar to those that exist in Pottawatomie Valley, between Lane and Osawatomie (see p. 258). The Iola limestone protects the bluffs on both sides of the river from Benedict almost to Neosho, while below this it caps the bluffs on the west almost to Independence. The height of the bluffs throughout the distance gradually increases to the south, being about 75 feet at Benedict and nearly 200 feet near Neodesha. Below Neodesha the eastern bluff gently recedes from the river, while the western bluff, though it has receded about 6 miles from the river, is almost precipitous.

## QUALITY OF WATER.

The United States Geological Survey maintained a daily sampling station on Verdigris River at Coffeyville from December 11, 1906, to December 11, 1907. D. M. Blair was collector.

A record of the analyses of composite samples is presented in Table 164. This table shows a calcic alkaline water that is not highly mineralized and has moderate temporary and low permanent hardness. The magnesium and chlorides are low and in all the samples a little iron is present.

[1] Kansas Univ. Geol. Survey, vol. 1, pp. 212–213.

The turbidity of the daily samples is recorded in Table 165. Of the 305 readings, nearly 50 per cent were below 50; nearly 36 per cent 100 or more, and somewhat more than 7 per cent were 1,000, or greater. The turbidity was low throughout February and from October 7 to November 22, except on November 4, when it was 90. The turbidity was high from January 9 to 29, from March 3 to 19, and from April 28 to June 2. The lowest turbidity, 4, occurred on December 28, 1906, and the highest, 10,200, on April 1, 1907. Except in the samples of December 11 to 20, 1906, June 17 to 26 and November 1 to 10, 1907, the coefficient of fineness, Table 164, was high, indicating that the solids carried in suspension by the river are coarse.

At Madison, analysis 1, Table 166, the water of Verdigris River has high temporary and permanent hardness, but farther downstream, analyses 2 and 3, Table 166, both the permanent and temporary hardness are low; at Guilford, however, analysis 4, Table 166, both rise again.

Tests of Verdigris River water at Independence (analyses 14, 15, and 16, Table 166) indicate that it is soft.

A test of Onion Creek, which enters Verdigris River south of Coffeyville, is recorded in assay 10, Table 167. As the creek was in flood when the sample was taken, the assay probably does not show the normal character of the water.

TABLE 164.—*Analyses of water from Verdigris River at Coffeyville, Kans.*

[Drainage area 3,250 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. Dec. 11 | 1906. Dec. 20 | 40 | 11 | 0.28 | 17 | 2.0 | 78 | 12 | 31 | 0.0 | 287 | 32 | 2.7 | 22 | 329 |
| Dec. 21 | 1907. Jan. 2 | 7 | 6.4 | .91 | 23 | .40 | 95 | 10.5 | 31 | .0 | 367 | 40 | 3.5 | 32 | 384 |
| 1907. Jan. 3 | Jan. 12 | 107 | 77 | .72 | 24 | 1.4 | 71 | 4.3 | 33 | a 9.6 | 290 | 44 | 4.2 | 38 | 364 |
| Jan. 13 | Jan. 22 | 874 | 688 | .79 | 34 | 1.0 | 46 | 1.3 | 32 | .0 | 164 | 25 | 7.9 | 10 | 224 |
| Jan. 23 | Feb. 1 | 327 | 230 | .70 | 22 | 3.0 | 79 | 4.1 | 29 | a 9.6 | 284 | 33 | 5.8 | 15 | 321 |
| Feb. 2 | Feb. 11 | 18 | 34 | 1.89 | 23 | .10 | 62 | 16 | 37 | .0 | 359 | 41 | 2.5 | 23 | 291 |
| Feb. 12 | Feb. 21 | 13 | 15 | 1.15 | 76 | .10 | 106 | 16 | 41 | .0 | 370 | 46 | 4.1 | 23 | 481 |
| Feb. 22 | Mar. 3 | 65 | 64 | .98 | 67 | .20 | 88 | 16 | 44 | .0 | 294 | 39 | 3.0 | 24 | 444 |
| Mar. 4 | Mar. 13 | 380 | 345 | .91 | 33 | .36 | 73 | 12 | 35 | .0 | 248 | 40 | 3.2 | 14 | 324 |
| Mar. 14 | Mar. 23 | 211 | 175 | .83 | 16 | 5.0 | 79 | 11 | 33 | a 3.1 | 265 | 30 | 3.0 | 13 | 317 |
| Mar. 24 | Apr. 1 | 1,877 | 2,190 | 1.17 | 13 | 2.0 | 80 | 7.2 | 31 | .0 | 288 | 30 | 4.0 | 19 | 323 |
| Apr. 2 | Apr. 14 | 188 | 142 | .76 | 16 | 4.0 | 69 | 2.0 | 25 | .0 | 237 | 30 | 2.9 | 18 | 278 |
| Apr. 15 | Apr. 26 | 103 | 100 | .97 | 16 | 1.8 | 78 | 11 | 31 | .0 | 315 | 35 | 2.8 | 28 | 326 |
| Apr. 28 | May 7 | 1,805 | 2,346 | 1.30 | 13 | 3.0 | 64 | 1.2 | 28 | .0 | 210 | 36 | 5.0 | 25 | 266 |
| May 8 | May 19 | 1,307 | 2,296 | 1.76 | 18 | 3.0 | 70 | 5.5 | 28 | .0 | 222 | 40 | 6.5 | 14 | 282 |
| May 20 | May 31 | 203 | 403 | 1.98 | 17 | 1.2 | 81 | 16 | 27 | .0 | 318 | 39 | 3.8 | 22 | 325 |
| June 1 | June 16 | 900 | 1,010 | 1.12 | 22 | 9 | 57 | 11 | 18 | .0 | 252 | 24 | 3.5 | 20 | 398 |
| June 17 | June 26 | 2,700 | 1,397 | .52 | 21 | 1.4 | 68 | 12 | 27 | .0 | 220 | 27 | 7 | 16 | 259 |
| July 8 | July 17 | 165 | 269 | 1.63 | 30 | 1.5 | 65 | 16 | 44 | a 7.0 | 273 | 33 | .4 | 19 | 304 |

a Abnormal; computed as $HCO_3$ in the average.

TABLE 164.—*Analyses of water from Verdigris River at Coffeyville, Kans.*—Cont'd.

| Date. From— | To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1907. | | | | | | | | | | | | | | | |
| July 18 | July 29 | 58 | 86 | 1.48 | 27 | 1.5 | 68 | 13 | 34 | 0.0 | 290 | 33 | 3.0 | 19 | 246 |
| July 30 | Aug. 10 | 60 | 78 | 1.30 | 29 | 1.3 | 72 | 14 | 34 | .0 | 268 | 31 | 2.0 | 21 | 267 |
| Aug. 11 | Aug. 23 | 95 | 102 | 1.07 | 18 | .7 | 73 | 18 | 37 | 0 | 273 | 32 | .5 | 28 | 309 |
| Aug. 24 | Sept. 5 | 266 | 236 | .89 | 20 | .05 | 57 | 14 | 37 | .0 | 210 | 21 | 3.5 | 18 | 233 |
| Sept. 6 | Sept. 15 | 50 | 54 | 1.08 | 20 | .03 | 57 | 13 | 34 | .0 | 210 | 16 | 3.1 | 20 | 235 |
| Sept. 16 | Sept. 25 | 42 | 44 | 1.05 | 23 | .12 | 62 | 16 | 33 | .0 | 208 | 23 | .9 | 25 | 250 |
| Sept. 26 | Oct. 9 | 35 | 47 | 1.34 | 16 | .12 | 66 | 14 | 33 | .0 | 210 | 20 | 1.2 | 36 | 262 |
| Oct. 10 | Oct. 20 | 23 | 27 | 1.18 | 23 | .13 | 67 | 14 | 36 | .0 | 242 | 27 | .6 | 35 | 293 |
| Oct. 21 | Oct. 31 | 14 | 10 | .71 | 19 | .14 | 65 | 16 | 38 | .0 | 238 | 22 | .8 | 40 | 291 |
| Nov. 1 | Nov. 10 | 22 | 14 | .64 | 17 | .20 | 63 | 12 | 32 | .0 | 215 | 21 | 1.1 | 31 | 255 |
| Nov. 11 | Nov. 20 | 22 | 17 | .77 | 15 | .30 | 51 | 12 | 33 | .0 | 200 | 19 | .9 | 21 | 226 |
| Nov. 21 | Dec. 10 | 56 | 55 | .98 | 17 | .20 | 83 | 11 | 34 | .0 | 213 | 24 | 1.0 | 24 | 253 |
| Mean........ | | 388 | 405 | 1.06 | 24 | 1.4 | 71 | 11 | 33 | .0 | 261 | 31 | 3.2 | 23 | 302 |
| Per cent of anhydrous residue .... | | ...... | ...... | ...... | 7.4 | .6 | 21.8 | 3.4 | 10.1 | 39.2 | ..... | 9.5 | 1.0 | 7.0 | .... |

NOTE.—Analyses from December 11, 1906, to February 1, 1907, and from March 14 to November 20, 1907, by F. W. Bushong; from February 2 to March 13 and from November 21 to December 10, 1907, by Archie J. Weith.

TABLE 165.—*Turbidity of daily samples from Verdigris River at Coffeyville, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ...... | 7 | 36 | 15 | 10,200 | 1,992 | 55 | ...... | 30 | 100 | 50 | 10 | 180 |
| 2 | ...... | 7 | 36 | 21 | 650 | 2,472 | 210 | ...... | 40 | 150 | 80 | 15 | 18 |
| 3 | ...... | 5 | 20 | 532 | 425 | 1,500 | 16 | ...... | 25 | 145 | ...... | 12 | 120 |
| 4 | ...... | 15 | 20 | 765 | 350 | 473 | 27 | ...... | ...... | 140 | ...... | 90 | ...... |
| 5 | ...... | 11 | 20 | 666 | ...... | 1,770 | 7 | ...... | 55 | 24 | 70 | 16 | 45 |
| 6 | ...... | 13 | 50 | 562 | ...... | 1,410 | 15 | ...... | 368 | ...... | ...... | 12 | 40 |
| 7 | ...... | 10 | 8 | 418 | 160 | 4,850 | ...... | ...... | ...... | ...... | 24 | 12 | 36 |
| 8 | ...... | 9 | 6 | 200 | 75 | 1,732 | 33 | 90 | 14 | ...... | 15 | 10 | ...... |
| 9 | ...... | 330 | 6 | 170 | 105 | 400 | 3,372 | 120 | 14 | ...... | 36 | 16 | ...... |
| 10 | ...... | 340 | 7 | 150 | 55 | 966 | ...... | 85 | 16 | ...... | 18 | 24 | 50 |
| 11 | 50 | 190 | 3 | 125 | 105 | ...... | ...... | 666 | 47 | ...... | ...... | 24 | ...... |
| 12 | 50 | 150 | 8 | 140 | 55 | 510 | 6,380 | 302 | 50 | ...... | 60 | 24 | ...... |
| 13 | 45 | 240 | 15 | 600 | 14 | 562 | ...... | 56 | 48 | ...... | 24 | 70 | ...... |
| 14 | 40 | 243 | 11 | 632 | 80 | ...... | 450 | 24 | 15 | ...... | 16 | 18 | ...... |
| 15 | 32 | 75 | 7 | 412 | 26 | 5,400 | 90 | 60 | 13 | ...... | 15 | 16 | ...... |
| 16 | 14 | 270 | 18 | 317 | 85 | 2,640 | 100 | 36 | 13 | 10 | 12 | 12 | ...... |
| 17 | 10 | 1,200 | 18 | 200 | 65 | 332 | ...... | 115 | 130 | 15 | 30 | 15 | ...... |
| 18 | 9 | 886 | 10 | 180 | 55 | 325 | ...... | 15 | 130 | 60 | 18 | 12 | ...... |
| 19 | 12 | 425 | 36 | 105 | 36 | 200 | ...... | 16 | 22 | 80 | 24 | 18 | ...... |
| 20 | 10 | 1,732 | 5 | 75 | ...... | 210 | ...... | 28 | 60 | 45 | 12 | 15 | ...... |
| 21 | 8 | 1,866 | 5 | 75 | 55 | 130 | ...... | 65 | 18 | 12 | 15 | 15 | ...... |
| 22 | 10 | 1,800 | 10 | 65 | 385 | 300 | ...... | 150 | 90 | 90 | 15 | 32 | ...... |
| 23 | 6 | 1,264 | 18 | 45 | 150 | 300 | ...... | 10 | 312 | 15 | 16 | 18 | ...... |
| 24 | 5 | 632 | 10 | 28 | ...... | 150 | ...... | 120 | 280 | 60 | 12 | 200 | ...... |
| 25 | 10 | 520 | 10 | 18 | 115 | 308 | ...... | ...... | 520 | 36 | 15 | 165 | ...... |
| 26 | ...... | 290 | 12 | 18 | 55 | 200 | ...... | 55 | 1,200 | 36 | 12 | 70 | ...... |
| 27 | 5 | 200 | 12 | 40 | ...... | ...... | ...... | 62 | 235 | 10 | 10 | ...... | ...... |
| 28 | 4 | 100 | 11 | 800 | 220 | 210 | ...... | ...... | 135 | 10 | 12 | 24 | ...... |
| 29 | 5 | 120 | ...... | 40 | 966 | ...... | ...... | 60 | ...... | 8 | 12 | ...... | ...... |
| 30 | 9 | 65 | ...... | 150 | 2,400 | 60 | ...... | 36 | 145 | ...... | 10 | 24 | ...... |
| 31 | 7 | 45 | ...... | 5,598 | ...... | 160 | ...... | 30 | 120 | ...... | 24 | ...... | ...... |
| Mean... | 17 | 421 | 15 | 424 | 675 | 1,095 | 896 | 100 | 148 | 55 | 24 | 35 | 70 |

NOTE.—Averages: June 17 to 26, 2,700; September 6 to 15, 50. Turbidities of over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

TABLE 166.—*Analyses of water from Verdigris River and its tributaries in Kansas and Oklahoma.*

[Parts per million.]

| No. | Date. | Source. | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$).[a] | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Volatile and organic. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Nov. 7, 1902 | Verdigris River, at Madison | Atchison, Topeka & Santa Fe Ry. | 10 | ...... | 135 | 32 | 16 | 241 | ...... | 70 | ...... | 18 | ...... | ...... |
| 2 | ....do | Verdigris River, at Toronto | ....do | 14 | 2.2 | 53 | 6.2 | 19 | 94 | ...... | 32 | ...... | 6 | ...... | ...... |
| 3 | ....do | Verdigris River, at Benedict | ....do | 18 | 1.5 | 50 | 10 | 1.5 | 79 | ...... | 26 | ...... | 9.1 | ...... | ...... |
| 4 | ...... | Verdigris River, at Guilford | Missouri Pacific Ry | 8.7 | 2.2 | 77 | 13 | 14 | 126 | ...... | 43 | ...... | 16 | 2.7 | 305 |
| 5 | Nov. 7, 1902 | Pond at Thayer | Atchison, Topeka & Santa Fe Ry. | 92 | 8.4 | 9.8 | 5 | 11 | 27 | ...... | 6 | ...... | 12 | ...... | ...... |
| 6 | ....do | Fall River, at Fredonia | ....do | 10 | Tr. | 91 | 23 | 13 | 169 | ...... | 44 | ...... | 19 | ...... | ...... |
| 7 | ...... | Fall River (city waterworks), at Fredonia. | Missouri Pacific Ry | 21 | 15 | 47 | 9.1 | 3.1 | 75 | ...... | 34 | ...... | 1.2 | 21 | 232 |
| 8 | ...... | Fall River (city waterworks), at Neodesha. | ....do | 13 | .2 | 76 | 12 | 15 | 137 | ...... | 22 | ...... | 16 | 59 | 351 |
| 9 | Nov. 7, 1902 | Rock Creek, at Howard | Kennicott Water Softener Co | 21 | .7 | 54 | 11 | 11 | 92 | ...... | 34 | ...... | 12 | ...... | ...... |
| 10 | ....do | Pond at Moline | Atchison, Topeka & Santa Fe Ry. | 15 | 1.7 | 31 | 7.8 | 12 | 60 | ...... | 17 | ...... | 11 | ...... | ...... |
| 11 | ....do | Duck Creek, at Elk | ....do | 43 | 1.9 | 30 | 5 | 11 | 34 | ...... | 45 | ...... | 12 | ...... | ...... |
| 12 | ...... | Elk River, at Elk | Missouri Pacific Ry | 25 | 6 | 44 | 8.2 | 7.6 | 77 | ...... | 15 | ...... | 11 | 14 | 210 |
| 13 | Jan. 20, 1908 | Elk River, at Independence | F. W. Bushong | 29 | .16 | 86 | 14 | 27 | ...... | 272 | 42 | 3 | 13 | ...... | 323 |
| 14 | Nov. 7, 1902 | Verdigris River, at Independence | Atchison, Topeka & Santa Fe Ry. | 4.3 | 3 | 32 | 6.4 | 8.7 | 56 | ...... | 10 | ...... | 15 | ...... | ...... |
| 15 | Mar. 31, 1903 | Verdigris River (city waterworks), at Independence. | ....do | 20 | ...... | 82 | 11 | 16 | 137 | ...... | 36 | ...... | 16 | 41 | ...... |
| 16 | ...... | ....do | Missouri Pacific Ry | 5.5 | .5 | 32 | 9.3 | 20 | 64 | ...... | 13 | ...... | 28 | 8.6 | 181 |
| 17 | Nov. 7, 1902 | Pond at Cherryvale | Atchison, Topeka & Santa Fe Ry. | 12 | .7 | 34 | 5.2 | 15 | 47 | ...... | 25 | ...... | 24 | ...... | ...... |
| 18 | ...... | Verdigris River (city waterworks), at Coffeyville. | Missouri Pacific Ry | 12 | 1.4 | 50 | 8.8 | 8.8 | 81 | ...... | 27 | ...... | 13 | 20 | 222 |
| 19 | Nov. 7, 1902 | Caney River, at Cedarvale | Kennicott Water Softener Co | 11 | ...... | 96 | 17 | 5.6 | 169 | ...... | 16 | ...... | 15 | ...... | ...... |
| 20 | ...... | ....do | Missouri Pacific Ry | 7 | 1.9 | 88 | 24 | 8.2 | 166 | ...... | 48 | ...... | 7.7 | 21 | 370 |
| 21 | Nov. 7, 1902 | Caney River, at Elgin | Atchison, Topeka & Santa Fe Ry. | 17 | 1.4 | 62 | 9.9 | 18 | 109 | ...... | 40 | ...... | 9 | ...... | ...... |
| 22 | ...... | Caney Creek, at Sedan | Missouri Pacific Ry | 12 | 1.5 | 68 | 9.9 | 16 | 119 | ...... | 21 | ...... | 18 | 17 | 283 |
| 23 | Nov. 7, 1902 | Bee Creek, at Havana | Kennicott Water Softener Co | 101 | 2.9 | 9.3 | 3.9 | 3.5 | 21 | ...... | 5.2 | ...... | 4.3 | ...... | ...... |
| 24 | Sept. 12, 1899 | Caney Creek, at Caney | Atchison, Topeka & Santa Fe Ry. | ...... | ...... | 51 | 8.9 | 14 | 92 | ...... | 11 | ...... | 22 | 94 | 298 |
| 25 | ...... | Caney Creek (Caney waterworks), at Caney. | Missouri Pacific Ry | 7 | .2 | 106 | 18 | 86 | 180 | ...... | 44 | ...... | 126 | 53 | 620 |
| 26 | Apr. 10–15, 1908 | Caney Creek, at Caney[b] | Archie J. Weith | 13 | .32 | 50 | 9.6 | 36 | ...... | 160 | 38 | 3 | 24 | ...... | 224 |
| 27 | Nov. 7, 1902 | Caney River, at Bartlesville, Okla | Atchison, Topeka & Santa Fe Ry. | 29 | 1 | 42 | 6.5 | 15 | 73 | ...... | 17 | ...... | 19 | ...... | ...... |

[a] Obtained by computation to ionic form; results originally stated as in hypothetical combinations.

[b] Composite samples.

TABLE 167.—*Assays of water of tributaries of Verdigris River in Kansas.*

[Parts per million.]

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | 1907. | | | | | | | |
| 1 | May 13 | Fall River, 500 feet above sewer outfall at Eureka. | 0.0 | 0.0 | 302 | Trace. | 10 | |
| 2 | May 2 | Salt Creek, at Atchison, Topeka & Santa Fe Ry. bridge, Fredonia. | .0 | .0 | 89 | 50 | 55 | Heavy rain on April 29. |
| 3 | ...do..... | Fall River, east of Atchison, Topeka & Santa Fe Ry. bridge, Fredonia. | .0 | .0 | 151 | 38 | 20 | Do. |
| 4 | May 6 | Fall River, at water works intake, Neodesha. | .0 | .0 | 140 | 37 | 14 | River in high stage. |
| 5 | May 14 | Elk River, at highway bridge, Howard. | .0 | .0 | 186 | Trace. | 10 | Do. |
| 6 | ...do..... | Mound Creek, at Atchison, Topeka & Santa Fe Ry. Bridge 78, south of Howard. | .0 | .0 | 117 | 42 | 14 | Creek in high stage. |
| 7 | May 3 | Elk River, 300 yards above mouth of Duck Creek, Elk. | .0 | .0 | 129 | 50 | 10 | Rain on night of May 2. |
| 8 | ...do..... | Duck Creek, at Main Street Bridge, Elk. | .0 | .0 | 102 | 46 | 14 | Do. |
| 9 | May 4 | Elk River, at Sycamore Road Bridge, Independence. | .0 | .0 | 138 | Trace. | 10 | |
| 10 | May 6 | Onion Creek, near Missouri Pacific Ry. bridge, Dearing. | .0 | .0 | 30 | Trace. | 20 | Creek in high stage. |
| 11 | May 10 | Caney River, at the old dairy, Cedarvale. | .0 | 12.0 | 256 | Trace. | 10 | |
| 12 | ...do..... | Cedar Creek, Cedarvale.... | .0 | .0 | 288 | Trace. | 10 | |
| 13 | May 9 | Deer Creek, at dam north of Missouri Pacific Ry., Sedan. | .0 | .0 | 240 | Trace. | 10 | Creek in high stage and heavily streaked with oil. |
| 14 | ...do.... | Caney Creek, 350 feet above water works intake, Sedan. | .0 | .0 | 227 | Trace. | 14 | Creek in high stage. |
| 15 | May 7 | Caney Creek, at Missouri Pacific Ry. bridge, west of Peru. | .0 | .0 | 153 | Trace. | 24 | Creek in high stage and streaked with oil. |
| 16 | ...do..... | North Caney Creek, at Missouri Pacific Ry. bridge, northeast of Peru Junction. | .0 | .0 | 139 | Trace. | 10 | Do. |
| 17 | ...do..... | Caney Creek, 100 feet north of Missouri Pacific Ry. bridge, Caney. | .0 | .0 | 133 | Trace. | 34 | Do. |
| 18 | ...do..... | Cheyenne Creek, at Missouri Pacific Ry. bridge east of new waterworks, Caney. | .0 | .0 | 35 | Trace. | 14 | Creek in high stage. |

NOTE.—Trace in the sulphate column means less than 35 parts per million.

## FALL RIVER.

### DESCRIPTION.

Fall River rises in the Flint Hills of Butler County, is 96 miles long, and has a fall of from 1,500 to 750 feet in a distance of 43 miles. Its drainage area is 848 square miles. As its basin is characterized by steep impervious slopes the run-off is rapid, and the stream is flashy. On the evening of April 23, 1904, the gage at Fall River read 4 feet; the next morning it read 26.3 feet, a rise of 24.3 feet in 10 hours. On the evening of June 15 the gage read 7.8; the next morning it read 37.8 feet, a rise of 30 feet in 10 hours. There were six floods on this river from April 23 to July 8, 1904, in which the gage read above 22 feet, and four when it read above 25 feet.[1]

The width of the river near its mouth at ordinary low water is 74 feet.

### QUALITY OF WATER.

The United States Geological Survey maintained a daily sampling station on Fall River at Neodesha from July 1, 1907, to May 25, 1908. The collector was J. J. Carrol.

A record of the analyses of composite samples appears in Table 168. The table shows a calcic alkaline water of moderate temporary and low permanent hardness similar to that of Verdigris River. Below the sampling point at Neodesha, Fall River receives certain wastes of the Standard Oil Co.'s refinery.

The record of the daily turbidity of Fall River at Fall River, from August 1, 1904, to July 31, 1905, is given in Table 169. The readings show that about 45 per cent of the time the turbidity was less than 50. A long period of low turbidity extended from October 31, 1904, to March 16, 1905, and a long period of high turbidity extended from May 13 to July 17, 1905. The lowest observed turbidity, 22, was recorded many times during the year, and the highest, 9,000, on July 3, 1905. A very incomplete record of the turbidity of the daily samples from the river at Neodesha appears in Table 170. The coefficient of fineness, Table 168, is high, except in the samples of March 10 to 20 and May 25 to June 10, indicating that the matter carried in suspension by the river is coarse.

Tests of Fall River at different times and places (assays 1, 3, and 4, Table 167, and analyses 6, 7, and 8, Table 166) show that the chlorides are low, the temporary hardness moderate, and that the permanent hardness, though variable, is usually low. The water of Salt Creek, a small tributary which joins the river at Fredonia, is shown by assay 2, Table 167, to be somewhat higher in sulphates and chlorides than the main stream.

[1] Murphy, E. C., Floods in the United States in 1904: Water-Supply Paper No. 147, U. S. Geol. Survey p. 105.

TABLE 168.—*Analyses of water from Fall River at Neodesha, Kans.*

[Drainage area, 848 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1907. | 1907. | | | | | | | | | | | | | | |
| July 1 | July 12 | 93 | 80 | 0.86 | 33 | 6 | 71 | 19 | 25 | 0.0 | 240 | 25 | 3.8 | 9 | 244 |
| July 13 | July 27 | 15 | 26 | 1.73 | 28 | 1.6 | 62 | 18 | 28 | .0 | 300 | 30 | 3.0 | 15 | 269 |
| July 28 | Aug. 8 | 13 | 30 | 2.31 | 22 | .7 | 64 | 22 | 28 | .0 | 292 | 27 | 1.1 | 14 | 286 |
| Aug. 9 | Aug. 18 | 10 | 19 | 1.90 | 34 | .30 | 59 | 17 | 27 | .0 | 285 | 24 | 1.2 | 17 | 271 |
| Aug. 20 | Aug. 31 | 684 | 487 | .71 | 16 | .24 | 51 | 12 | 24 | .0 | 180 | 18 | 2.0 | 10 | 195 |
| Sept. 1 | Sept. 11 | 85 | 84 | .99 | 23 | .22 | 48 | 8.8 | 24 | .0 | 165 | 14 | 2.5 | 8.5 | 194 |
| Sept. 12 | Sept. 23 | 45 | 40 | .89 | 17 | .04 | 60 | 9.9 | 24 | .0 | 182 | 15 | .5 | 10 | 190 |
| Sept. 24 | Oct. 26 | 20 | 22 | 1.10 | 19 | .12 | 64 | 11 | 25 | .0 | 215 | 16 | .9 | 12 | 424 |
| Oct. 27 | Nov. 8 | 16 | 14 | .88 | 23 | .08 | 61 | 17 | 29 | .0 | 265 | 17 | .8 | 17 | 253 |
| Nov. 9 | Dec. 13 | 11 | 10 | .91 | 18 | .12 | 74 | 17 | 32 | .0 | 290 | 21 | .6 | 25 | 304 |
| Dec. 14 | Dec. 24 | 95 | 76 | .80 | 23 | .30 | 75 | 14 | 33 | .0 | 270 | 29 | 1.5 | 14 | 283 |
| 1908. | 1908. | | | | | | | | | | | | | | |
| Jan. 16 | Jan. 28 | 50 | 43 | .86 | 35 | .16 | 81 | 15 | 34 | .0 | 290 | 41 | 2.2 | 14 | 340 |
| Jan. 29 | Feb. 14 | 36 | 35 | .97 | 33 | .12 | 85 | 16 | 36 | .0 | 312 | 41 | 2.0 | 14 | 357 |
| Feb. 15 | Feb. 17 | 18 | ..... | ...... | ..... | ...... | ...... | ..... | ...... | .0 | 276 | ...... | ...... | 14 | .... |
| Mar. 10 | Mar. 20 | 50 | 32 | .64 | 20 | .18 | 79 | 13 | 33 | .0 | 270 | 62 | 3.5 | 11 | 322 |
| Mar. 21 | Mar. 31 | 16 | 20 | 1.25 | 21 | .12 | 73 | 16 | 40 | .0 | 300 | 42 | 2.5 | 13 | 303 |
| Apr. 5 | Apr. 14 | 180 | 118 | .66 | 28 | .14 | 68 | 11 | 31 | [a]8.9 | 211 | 32 | 3.1 | 10 | 279 |
| Apr. 15 | Apr. 24 | 295 | 247 | .84 | 39 | .20 | 63 | 11 | 32 | [a]16 | 177 | 34 | 3.7 | 13 | 282 |
| Apr. 25 | May 5 | 70 | 62 | .88 | 28 | .06 | 79 | 14 | 36 | .0 | 200 | 34 | 1.0 | 10 | 344 |
| May 5 | May 14 | 50 | 79 | 1.58 | 41 | .20 | 55 | 14 | 35 | .0 | 228 | 34 | .5 | 9.9 | 283 |
| May 15 | May 24 | 824 | 627 | .76 | 48 | 1.40 | 55 | 12 | 34 | .0 | 241 | 27 | 2.8 | 7.6 | 282 |
| May 25 | June 10[b] | 2,100 | 802 | .38 | 31 | .14 | 69 | 11 | 28 | [a]8.8 | 69 | 26 | .5 | 9.3 | 283 |
| Mean........ | | 217 | 141 | 1.04 | 28 | .59 | 66 | 14 | 30 | .0 | 242 | 29 | 1.9 | 13 | 285 |
| Per cent of anhydrous residue..... | | ...... | ..... | ...... | 9.3 | .3 | 21.9 | 4.6 | 10.0 | 39.4 | ...... | 9.6 | .6 | 4.3 | .... |

[a] Abnormal, computed as $HCO_3$ in the average. [b] About June 10; 13 samples.

NOTE.—Analyses from July 1, 1907, to February 17, 1908, by F. W. Bushong; from March 10 to June 10, 1908, by Archie J. Weith.

TABLE 169.—*Daily turbidity measurements of Fall River at Fall River, Kans., and daily gage heights at Fall River.*

[J. McDaniel, observer.]

| Day. | 1904. | | | | | | | | | | 1905. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August. | | September. | | October. | | November. | | December. | | January. | | February. | | March. | | April. | | May. | | June. | | July. | |
| | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. |
| 1 | 350 | 3.90 | 30 | 2.40 | 40 | 2.40 | 40 | 2.20 | 30 | ...... | 25 | 2.2 | 22 | 2.0 | 200 | 3.2 | 40 | 2.4 | 50 | 2.4 | 300 | 3.4 | 300 | 3.8 |
| 2 | 100 | 4.10 | 30 | 2.40 | 40 | 2.40 | 40 | 2.20 | 30 | ...... | 24 | 2.1 | 22 | 2.0 | 180 | 3.0 | 200 | 2.4 | 50 | 2.4 | 300 | 3.6 | 3,000 | 4.0 |
| 3 | 75 | 3.65 | 30 | 2.30 | 60 | 2.40 | 35 | 2.20 | 30 | ...... | 24 | 2.1 | 22 | 2.0 | 100 | 3.0 | 300 | 2.9 | 150 | 2.4 | 3,000 | 6.8 | 9,000 | 17.5 |
| 4 | 70 | 3.45 | 30 | 2.20 | 100 | 2.40 | 35 | 2.20 | 30 | ...... | 24 | 2.0 | 22 | 2.0 | 80 | 2.8 | 100 | 2.6 | 150 | 2.4 | 600 | 4.0 | 3,000 | 7.5 |
| 5 | 65 | 3.25 | 30 | 2.20 | 100 | 2.40 | 35 | 2.20 | 30 | ...... | 24 | 2.0 | 22 | 2.0 | 75 | 2.6 | 50 | 2.6 | 100 | 2.4 | 300 | 3.6 | 800 | 5.75 |
| 6 | 60 | 3.05 | 25 | 2.20 | 100 | 2.40 | 35 | 2.20 | 30 | ...... | 22 | 2.0 | 22 | 2.0 | 70 | 2.4 | 35 | 2.4 | 100 | 2.4 | 200 | 3.6 | 300 | 5.4 |
| 7 | 40 | 3.00 | 25 | 2.20 | 90 | 2.40 | 30 | 2.20 | 28 | ...... | 22 | 2.0 | 22 | 2.0 | 65 | 2.4 | 30 | 2.4 | 100 | 2.4 | 180 | 3.6 | 200 | 5.0 |
| 8 | 40 | 3.00 | 25 | 2.20 | 80 | 2.40 | 30 | 2.10 | 28 | ...... | 22 | 2.0 | 22 | 2.0 | 60 | 2.3 | 30 | 2.4 | 100 | 2.4 | 180 | 3.5 | 200 | 4.7 |
| 9 | 35 | 3.00 | 25 | 2.15 | 80 | 2.40 | 30 | 2.10 | 28 | ...... | 22 | 2.0 | 22 | 2.0 | 55 | 2.3 | 30 | 2.4 | 100 | 2.4 | 180 | 3.5 | 180 | 5.6 |
| 10 | 35 | 3.00 | 25 | 2.10 | 80 | 2.40 | 30 | 2.10 | 28 | ...... | 22 | 2.0 | 22 | 2.0 | 40 | 2.3 | 30 | 2.4 | 90 | 2.4 | 180 | 3.2 | 180 | 5.0 |
| 11 | 35 | 3.00 | 500 | 2.10 | 80 | 2.40 | 30 | 2.10 | 28 | ...... | 22 | 2.0 | 22 | 2.0 | 35 | 2.2 | 100 | 2.4 | 90 | 2.4 | 300 | 3.2 | 180 | 4.6 |
| 12 | 35 | 2.90 | 150 | 2.10 | 80 | 2.45 | 30 | 2.10 | 28 | ...... | 22 | 2.0 | 22 | 2.0 | 35 | 2.1 | 75 | 2.4 | 75 | 2.4 | 300 | 3.2 | 180 | 4.1 |
| 13 | 35 | 2.80 | 80 | 2.10 | 80 | 2.40 | 30 | 2.10 | 25 | ...... | 22 | 2.0 | 22 | 2.0 | 28 | 2.1 | 50 | 2.4 | 150 | 2.4 | 200 | 3.2 | 150 | 3.75 |
| 14 | 30 | 2.70 | 40 | 2.10 | 80 | 2.35 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 22 | 2.0 | 28 | 2.1 | 50 | 2.4 | 150 | 2.4 | 180 | 3.0 | 150 | 3.6 |
| 15 | 30 | 2.70 | 40 | 2.10 | 80 | 2.35 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 22 | 2.0 | 28 | 2.1 | 50 | 2.4 | 150 | 2.4 | 120 | 3.0 | 120 | 3.6 |
| 16 | 30 | 2.70 | 35 | 2.10 | 80 | 2.35 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 22 | 2.0 | 28 | 2.1 | 50 | 2.4 | 150 | 2.4 | 6,000 | 11.3 | 120 | 3.6 |
| 17 | 100 | 2.70 | 35 | 2.10 | 80 | 2.30 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 22 | 2.0 | 300 | 2.1 | 50 | 2.4 | 100 | 2.4 | 6,000 | 8.0 | 100 | 3.55 |
| 18 | 3,000 | 3.65 | 35 | 2.05 | 80 | 2.30 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 22 | 2.0 | 500 | 2.8 | 40 | 2.3 | 150 | 2.4 | 3,000 | 6.0 | 80 | 3.6 |
| 19 | 150 | 3.40 | 30 | 2.00 | 75 | 2.30 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 22 | 2.0 | 300 | 2.6 | 40 | 2.3 | 200 | 2.4 | 3,000 | 4.0 | 75 | 3.5 |
| 20 | 500 | 3.25 | 30 | 2.00 | 75 | 2.30 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 22 | 2.0 | 200 | 2.4 | 40 | 2.3 | 200 | 2.4 | 600 | 3.6 | 70 | 3.5 |
| 21 | 350 | 3.70 | 30 | 2.00 | 75 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 70 | 2.8 | 100 | 2.4 | 30 | 2.3 | 150 | 2.4 | 300 | 3.6 | 70 | 3.5 |
| 22 | 300 | 3.55 | 500 | 2.40 | 70 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 350 | 3.6 | 75 | 2.8 | 30 | 2.3 | 150 | 2.4 | 200 | 3.6 | 70 | 3.5 |
| 23 | 150 | 3.50 | 150 | 2.40 | 70 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 500 | 4.6 | 50 | 2.6 | 30 | 2.8 | 130 | 2.4 | 180 | 3.6 | 65 | 3.4 |
| 24 | 90 | 3.45 | 80 | 2.35 | 65 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 500 | 4.0 | 40 | 2.4 | 100 | 2.8 | 130 | 2.4 | 150 | 3.6 | 65 | 3.3 |
| 25 | 80 | 3.30 | 60 | 2.25 | 65 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 400 | 3.5 | 40 | 2.4 | 150 | 2.6 | 300 | 2.4 | 120 | 3.6 | 60 | 3.2 |
| 26 | 60 | 2.95 | 40 | 2.30 | 60 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 350 | 3.5 | 35 | 2.4 | 100 | 2.4 | 200 | 2.4 | 100 | 3.6 | 55 | 3.2 |
| 27 | 40 | 2.75 | 40 | 2.40 | 60 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 300 | 3.2 | 30 | 2.3 | 75 | 2.4 | 180 | 2.6 | 100 | 3.5 | 55 | 3.0 |
| 28 | 40 | 2.60 | 40 | 2.40 | 55 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | 250 | 3.0 | 200 | 2.2 | 50 | 2.4 | 200 | 2.8 | 100 | 3.5 | 55 | 2.9 |
| 29 | 35 | 2.60 | 40 | 2.40 | 55 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | ...... | ...... | 200 | 2.2 | 50 | 2.4 | 500 | 4.9 | 200 | 3.6 | 55 | 2.8 |
| 30 | 30 | 2.50 | 40 | 2.40 | 50 | 2.20 | 30 | 2.00 | 25 | ...... | 22 | 2.0 | ...... | ...... | 100 | 2.4 | 50 | 2.4 | 500 | 6.0 | 200 | 3.6 | 50 | 3.0 |
| 31 | 30 | 2.45 | .... | ...... | 40 | 2.20 | .... | ...... | 25 | ...... | 22 | 2.0 | ...... | ...... | 50 | 2.4 | ...... | ...... | 400 | 3.2 | ...... | ...... | 300 | 3.0 |
| Mean | 194 | ...... | 76 | ...... | 72 | ...... | 31 | ...... | 26 | ...... | 22 | ...... | 112 | ...... | 107 | ...... | 68 | ...... | 169 | ...... | 892 | ...... | 622 | ...... |

TABLE 170.—*Turbidity of Fall River at Neodesha, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | 1907. | | | | | |
|---|---|---|---|---|---|---|
| | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | 430 | 14 | 120 | ........ | 10 | ........ |
| 2 | 80 | 3 | 80 | ........ | 18 | ........ |
| 3 | 100 | 4 | ........ | ........ | 18 | ........ |
| 4 | 70 | ........ | ........ | ........ | ........ | ........ |
| 5 | 60 | 18 | ........ | ........ | 12 | ........ |
| 6 | ........ | ........ | ........ | ........ | 10 | 15 |
| 7 | 48 | 15 | ........ | 36 | 10 | 15 |
| 8 | 50 | 20 | ........ | 18 | 10 | 12 |
| 9 | 48 | 9 | ........ | 32 | 10 | 10 |
| 10 | 24 | 9 | ........ | ........ | 12 | 10 |
| 11 | ........ | 13 | ........ | 32 | ........ | 12 |
| 12 | 22 | 10 | ........ | 18 | ........ | 8 |
| 13 | 18 | 13 | ........ | ........ | ........ | 10 |
| 14 | 22 | 7 | ........ | ........ | ........ | 10 |
| 15 | 10 | 5 | ........ | 18 | ........ | 16 |
| 16 | 26 | 10 | ........ | ........ | ........ | 10 |
| 17 | 16 | 10 | ........ | 15 | ........ | 5 |
| 18 | 18 | 8 | ........ | ........ | ........ | ........ |
| 19 | 24 | ........ | ........ | ........ | ........ | 8 |
| 20 | 22 | 12 | ........ | ........ | ........ | 10 |
| 21 | ........ | 15 | ........ | ........ | ........ | 8 |
| 22 | ........ | 15 | ........ | ........ | ........ | 310 |
| 23 | ........ | 3,792 | ........ | ........ | ........ | 290 |
| 24 | ........ | 833 | 24 | ........ | ........ | 280 |
| 25 | ........ | 1,000 | 12 | 15 | ........ | ........ |
| 26 | 6 | 500 | 12 | 15 | ........ | ........ |
| 27 | 6 | 765 | ........ | 12 | ........ | ........ |
| 28 | 10 | 370 | ........ | 24 | ........ | ........ |
| 29 | 22 | 280 | ........ | 24 | ........ | ........ |
| 30 | 10 | 260 | 16 | ........ | ........ | ........ |
| 31 | 14 | 385 | ........ | ........ | ........ | ........ |
| Mean | 48 | 300 | 44 | 22 | 12 | 58 |

NOTE.—September, 1907, averages: 1 to 11, 85; 12 to 23, 45. January, 1908, average: 16 to 28, 50. March, 1908, averages: 10 to 20, 50; 21 to 31, 16. April, 1908, averages: 5 to 14, 180; 15 to 24, 295; 25 to May 4, 70. May, 1908, averages: 5 to 14, 50; 15 to 24, 824. Turbidities of over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

## ELK RIVER.

### DESCRIPTION.

Elk River is formed by the union of Ham and Clear creeks south of Western Park, in the northwestern part of Elk County, whence it flows southeasterly and empties into Verdigris River about 2½ miles north of Independence. Its drainage area comprises 687 square miles. The river is 70 miles long, and near its mouth at ordinary low water 75 feet wide. It falls from an elevation of 1,500 feet to 750 feet in a distance of 43 miles. Its discharge is smaller and its flow less steady than that of Fall River, resembling the main stream in this respect.

### QUALITY OF WATER.

Tests of the water of Elk River and its tributaries, assays 4 to 9, Table 167, and analyses 9 to 13, Table 166 (p. 316), indicate that all of the waters have little temporary and most of them slight permanent hardness.

## CANEY RIVER.

### DESCRIPTION.

Caney River rises in the Flint Hills in the southwest corner of Union Center Township, north of Greenola, near the western boundary of Elk County, and flows southward to Cedarvale in Chautauqua County, where it turns and flows southeastward, passing into the Osage Nation, Okla., at a point west of Elgin, Kans. It then flows southward, emptying into Verdigris River in Rogers County, Okla. The principal tributary of Caney River is Caney Creek, which rises in Greenfield Township, Elk County, Kans., and takes a general southeasterly course to its point of junction with Caney River in Washington County, Okla.

The local names of Caney River and its tributaries seem to be somewhat confused. The name Big Caney Creek is applied to a stream heading in Union Center Township, Elk County, Kans., flowing south to Cedarvale, thence southeastward into Washington County, Okla., where it unites with Little Caney Creek. The resulting stream, which is called Little Verdigris River, flows southward into Rogers County, Okla., and unites with Verdigris River. Little Caney Creek is formed by the confluence of North Caney Creek and Middle Caney Creek in Washington Township, Chautauqua County, Kans.

In Kansas Caney River and its tributaries drain Chautauqua County, the southern part of Elk County, and the western part of Montgomery County. The basin of Caney River in Kansas lies in an important oil region, and most of the tributaries of the stream are heavily streaked with oil.

The entire drainage basin of Caney River[1] contains 2,440 square miles. The river is 140 miles long, and falls from an elevation of 1,500 feet at its source to 750 feet near the Kansas-Oklahoma State line, a distance of 48 miles.

### QUALITY OF WATER.

Tests of the water of Caney River and its tributaries in Kansas are recorded in assays 11 to 18, Table 167, and analyses 19 to 27, Table 166. Most of the creeks tested by water assays were in high stage at the time they were sampled. Both the analyses and assays indicate waters of moderate temporary and low permanent hardness.

## Neosho River.

### DESCRIPTION.

Neosho River rises west of Parkerville in Morris County, Kans., and flows southeastward across Lyon, Coffey, Woodson, Allen, Neosho, Labette, and Cherokee counties. Entering Oklahoma at a point

[1] Murphy, E. C., Destructive floods in the United States: Water-Supply Paper U. S. Geol. Survey No. 147, 1904, p. 95.

south of Melrose, it forms for a short distance the boundary between Craig and Ottawa counties, Okla., thence flows southeastward across Ottawa County to a point a little northwest of Wyandotte, where it turns and takes a general southwesterly course to its junction with Arkansas River at a point a little below the mouth of Verdigris River and west of Fort Gibson.

Its drainage basin, lying entirely within the humid belt, extends east and west from central Kansas to western Missouri about 200 miles and north and south about the same distance; its total drainage area comprises 12,660 square miles. To the north and east are the basins of Kansas and Osage rivers; to the south and west is the Verdigris. Measured by direct course, the length of the river is about 250 miles, but as it is a very crooked stream the distance along the bed is much greater. Within a distance of 136 miles the river falls from an elevation of approximately 1,500 feet above sea level near its source to 800 feet at a point about 27 miles north of the Kansas-Oklahoma line; and from this point to the mouth, a distance of 110 miles in a straight line, it falls about 300 feet.

A comparison of the Neosho with the Verdigris discloses some interesting features. Neosho River rises about 40 miles farther north and at an elevation about 100 feet greater. The streams flow in nearly parallel directions and empty into Arkansas River only a few hundred feet apart. The Verdigris falls more rapidly in its upper course than the Neosho, reaching the Kansas-Oklahoma State line at an elevation of 680 feet and falling 720 feet in about 151 miles; the Neosho falls more gradually, reaching the Kansas-Oklahoma State line at an elevation of about 770 feet, falling 730 feet in about 267 miles. From the Kansas-Oklahoma State line the Neosho falls about 270 feet and the Verdigris about 180. As a result of these differences in the topography of the basins, the Verdigris flows in a narrow, deep channel, while the Neosho is wider, has lower banks, and is subject to overflow in many places, notably near Chanute, Kans. Near the mouth the differences are more marked; the Verdigris is deeper, is 250 feet wide, and is sluggish, with scarcely a perceptible current at ordinary stage of water; the Neosho is from 600 to 800 feet wide, is shallow, and has a fairly rapid velocity.

The principal tributaries of the Neosho are Cottonwood River, which enters it from the west near Emporia, and Spring River, which enters it from Kansas in Ottawa County, Okla.

The area of land flooded along Neosho River is large compared with the size of the stream, and the same statement holds good of all the streams in southeastern Kansas. They have little fall and are very crooked, and the water, instead of running off quickly, is held back, overflows the banks, and spreads out over the river bottom to a width in places of 4 to 5 miles. The average fall of the stream from Emporia to the mouth is less than 2 feet per mile, and there are stretches 20 miles long, where the fall is only 1.7 feet per mile. In parts of its course the river is so crooked that 20 miles measured along the channel is less than half that distance in a direct course. These numerous bends, together with the trees that in places grow thickly to the water's edge, reduce the already small slope of the stream so much that its effective value is probably not more than 1¼ feet per mile. The upper part of the watershed is hilly pasture land, from which the water flows rapidly. The central and lower part is rolling, cultivated land. There are no forests on the watershed, but narrow strips of trees are found along the greater part of the stream. The drainage area of Neosho River at Oswego is 5,230 square miles.

The estimated monthly discharge of Neosho River at Iola is given in the following table:

TABLE 171.—*Mean monthly discharge of Neosho River at Iola, Kans., for period January 1, 1896, to November 30, 1903, inclusive.*

[Drainage area, 3,670 square miles.]

| Month. | Discharge in second-feet. | | |
|---|---|---|---|
| | Maximum. | Minimum. | Mean. |
| January | 985 | 1 | 332 |
| February | 8,490 | 1 | 738 |
| March | 12,290 | 20 | 1,280 |
| April | 19,250 | 50 | 2,190 |
| May | 45,560 | 160 | 5,060 |
| June | 39,120 | 75 | 4,400 |
| July | 21,365 | 87 | 1,200 |
| August | 24,550 | 10 | 1,730 |
| September | 18,500 | 1 | 1,170 |
| October | 20,150 | 0 | 1,150 |
| November | 30,411 | 1 | 1,200 |
| December | 16,077 | 1 | 731 |
| The period | 45,560 | 0 | 1,770 |

With the exception of Cottonwood River and the headwaters of a few tributary streams, the entire basin of the Neosho in Kansas lies within the Pennsylvanian.

The topographic features along Neosho River are interesting. Where the stream flows nearly at right angles to the line of outcrops of the different formations, the bluffs on both sides are about equal in height, but as it changes its relative direction, the south bluffs are in places less pronounced than those on the north. This difference in character of the bluffs results from the fact that the different limestone formations rise gradually toward the south, while toward the north the upturned edges of the same formations are eroded in such a way as to produce more nearly vertical walls. Farther downstream, where the river breaks through the Fort Scott ("Oswego") limestone, the east bluff line, which is in the Cherokee shale, has become a gentle slope, receding 4 or 5 miles from the river; and on the west the protective influence of the Fort Scott limestone is seen in the bluff at Oswego, which in places rises almost vertically to a height of 150 feet.[1]

[1] Kansas Univ. Geol. Survey, vol. 1, pp. 211-212.

## QUALITY OF WATER.

The United States Geological Survey maintained two daily sampling stations on Neosho River. The first was established at Emporia, with the help of Alva J. Smith, city engineer, and was continued from December 6, 1906, to December 3, 1907; Frank Bacon was collector. The second station was maintained at Oswego from December 11, 1906, to December 9, 1907; Nelie Nafus was collector.

The results of the analyses of the composite samples collected at Emporia appear in Table 172. The table shows a calcic alkaline water. The magnesium is low and some iron is present in all of the samples. The chlorides are low. The temporary hardness is usually moderate but fluctuates a good deal. The permanent hardness is low.

The daily turbidity of the Neosho at Emporia from August 1, 1904, to July 31, 1905, as determined by measurements made with a United States Geological Survey turbidity rod, is recorded in Table 173. Nearly 74 per cent of the time the turbidity was less than 50. A period of low turbidity extended from August 1, 1904, to January 22, 1905, and there were other periods of low turbidity extending over about 20 days each. No period of high turbidity lasted over 15 days. The lowest turbidity, 7, was recorded for a long period in February, and the highest turbidity, 3,000, was recorded daily from June 30 to July 4, 1905. The turbidity of the daily samples collected at Emporia in 1906–7 is recorded in Table 174. Of the 356 readings, over 64 per cent were less than 50 and over 15 per cent were 100 or over. From December 5, 1906, to January 19, 1907, from March 16 to June 7, 1907, from August 6 to October 3, 1907, and from October 18 to December 5, 1907, were long periods of low turbidity. There was no period of high turbidity 15 days in length. The lowest turbidity, 2, was recorded on February 5, 1907, and the highest, 6,000, on June 8, 1907. The coefficient of fineness, Table 172, was usually high, but nine times fell below 0.65, from which it may be concluded that, though the matter carried in suspension by the river at Emporia is usually coarse, there are times when the use of a coagulant to clarify the water would be advisable in filtration practice.

The results of the analyses of the composites of samples taken at Oswego are recorded in Table 175. The table shows that the water of the river here is not highly mineralized and that as a rule the amount of mineral matter held in solution varies directly with the gage height, rising and falling with it.

The water belongs to the calcic alkaline class and is less satisfactory in character than is that of the river at Emporia. The calcium, bicarbonates, and sulphates fluctuate more, and the sulphates are high enough in all of the samples to make treatment to remove them advisable when the water is to be used in steam boilers, whereas in the water of the Neosho at Emporia this is not necessary. At the two cities the iron content of the river water is about the same and so is the magnesium. The chlorides in the river water were about the same at the two stations. The change in the character of Neosho River water at Oswego is chiefly effected by the water of Cottonwood River, which enters the Neosho below Emporia and carries more sulphates than does any other considerable tributary of the Neosho. It also carries more magnesium than does the Neosho at either sampling station.

The daily turbidity of Neosho River at Oswego from June, 1904, to July, 1905, as determined with the United States Geological Survey turbidity rod, is shown in Table 176. About 38 per cent of the time the turbidity of the river was less than 50 and nearly 53 per cent of the time it was 100 or more. Long periods of high turbidity extended from June 1 to July 31, 1904, August 18 to 30, 1904, February 25 to April 22, 1905, May 11 to 23, 1905, and May 29 to July 24, 1905. Long periods of low turbidity extended from August 31 to September 22, 1904, September 25, 1904, to January 13, 1905, and February 11 to 24, 1905.

The turbidity of the daily samples taken at Oswego from December 11, 1906, to December 9, 1907, is shown by Table 177. Of 270 determinations, nearly 49 per cent were less than 50 and about 36 per cent were 100 or greater. Long periods of high turbidity extended from January 15 to February 3, 1907, March 3 to April 6, 1907, and April 30 to May 12, 1907. Long periods of low turbidity extended from December 11, 1906, to January 9, 1907, February 4 to 16, 1907, April 7 to 29, 1907, September 1 to November 3, 1907, and November 5 to 22, 1907. The lowest turbidity, 2, is recorded on December 19, 1906, and the highest, 2,100, on March 15, 1907. The coefficient of fineness, Table 175, was less than 0.65 only three times, and only eight times was less than 0.75, indicating that the suspended matter ordinarily is coarse.

A number of tests of the water carried by tributaries of the Neosho River, and at different points from Council Grove to Chetopa are recorded in Tables 178 and 179. Though these tributaries and that part of Neosho River that is above Council Grove flow mostly in the Permian deposits, their waters are neither highly mineralized nor high in sulphates, as is shown by assays 1 to 5, Table 178, and analysis 1, Table 179. Indeed, these results, together with assays 6 to 9, Table 178, and analyses 2 to 3, Table 179, indicate that from its source to the mouth of Cottonwood River the waters of Neosho River and its tributaries are soft, and this presage is confirmed by the analyses of composite samples of the river at Emporia.

The results of tests of the water of the Neosho River and its tributaries at different points between Burlington and Chetopa are recorded in assays 25 to 69, Table 178. In this distance the main stream and its branches lie practically wholly within rocks of the Pennsylvanian series and the waters of all have low permanent and moderate or low temporary hardness, except that Elm Creek (assays 34 and 35, Table 178) and Cherry Creek (assays 57 and 58, Table 178) are unlike the others. The reason for the high sulphates and low bicarbonates in assay 35 and the rather high sulphates in assay 36 was not investigated, but the low bicarbonates and high sulphates in the water of Cherry Creek (assay 58, Table 178) are due to the pollution of a tributary of Cherry Creek (assay 57) with mine water at Scammon. More detailed tests of the water of Neosho River at different places between Neosho Rapids and Chanute are recorded in analyses 15 to 20, Table 179. The sample at Neosho Rapids shows rather high carbonates and sulphates, but the other samples indicate waters of moderate temporary and low permanent hardness.

TABLE 172.—*Analyses of water from Neosho River at Emporia, Kans.*

[Drainage area, 740 (estimated) square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Dec. 5 | Dec. 14 | 40 | 28 | 0.70 | 21 | 1.4 | 79 | 13 | 25 | 0.0 | 324 | 27 | 0.3 | 12 | 315 |
| Dec. 15 | Dec. 24 | 14 | 14 | 1.00 | 17 | .30 | 86 | 13 | 35 | .0 | 344 | 23 | .2 | 12 | 317 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 25 | Jan. 4 | 14 | 8 | .57 | 28 | 1.4 | 88 | 12 | 22 | a11 | 326 | 31 | 4.0 | 10 | 332 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 5 | Jan. 14 | 9.5 | 6.8 | .72 | 18 | 1.6 | 67 | 11 | 32 | .0 | 356 | 27 | 2.6 | 14 | 262 |
| Jan. 15 | Jan. 24 | 700 | 540 | .77 | 43 | 3.6 | 62 | 4.8 | 29 | .0 | 259 | 31 | 4.4 | 6.8 | 278 |
| Jan. 25 | Feb. 4 | 20 | 19 | .95 | 39 | 1.2 | 82 | 8.5 | 33 | a6.7 | 304 | 36 | 5.3 | 6.3 | 346 |
| Feb. 5 | Feb. 14 | 273 | 198 | .72 | 21 | .40 | 64 | 12 | 25 | .0 | 245 | 36 | 5.9 | 6.1 | 284 |
| Feb. 15 | Feb. 24 | 65 | 47 | .72 | 41 | .24 | 70 | 8.4 | 19 | .0 | 244 | 27 | 4.6 | 5.5 | 300 |
| Feb. 25 | Mar. 6 | 907 | 757 | .83 | 57 | .68 | 64 | 9.0 | 28 | .0 | 226 | 25 | 4.9 | 4.5 | 319 |
| Mar. 7 | Mar. 16 | 870 | 725 | .83 | 16 | .20 | 64 | 11 | 38 | .0 | 213 | 44 | 4.8 | 4.2 | 238 |
| Mar. 17 | Mar. 26 | 37 | 22 | .59 | 19 | 1.2 | 99 | 16 | 24 | .0 | 347 | 30 | 4.8 | 5.4 | 350 |
| Mar. 27 | Apr. 5 | 47 | 33 | .70 | 6.0 | .50 | 76 | 11 | 24 | .0 | 287 | 33 | 1.4 | 4.8 | 283 |
| Apr. 6 | Apr. 15 | 52 | 39 | .75 | 3.6 | 2.5 | 72 | 7.5 | 24 | .0 | 290 | 34 | 1.5 | 8.2 | 270 |
| Apr. 16 | Apr. 26 | 31 | 17 | .55 | 3.8 | 3.5 | 69 | 17 | 22 | .0 | 289 | 35 | 2.3 | 9 | 285 |
| Apr. 27 | May 6 | 40 | 19 | .48 | 7.6 | 1.4 | 78 | 20 | 26 | .0 | 297 | 36 | 1.5 | 11 | 291 |
| May 7 | May 16 | 35 | 25 | .71 | 16 | 1.2 | 75 | ...... | 22 | .0 | 310 | 37 | 1.7 | 9 | 295 |
| May 17 | May 26 | 45 | 33 | .73 | 16 | 1.4 | 74 | 16 | 28 | .0 | 295 | 32 | 3.1 | 9 | 296 |
| May 27 | June 6 | 50 | 28 | .56 | 20 | 1.2 | 84 | 14 | 25 | .0 | 300 | 32 | 4.5 | 9 | 322 |
| June 7 | June 16 | 1,075 | 734 | .68 | 32 | 10 | 55 | 12 | 22 | .0 | 220 | 23 | 10 | 7 | 259 |
| June 17 | June 26 | 660 | 523 | .79 | 24 | 5 | 56 | 15 | 23 | a7.6 | 230 | 24 | 8.0 | 6.5 | 266 |
| June 27 | July 7 | 610 | 410 | .67 | 29 | 6 | 46 | 13 | 28 | .0 | 187 | 16 | 7.5 | 5.0 | 246 |
| July 8 | July 17 | 63 | 50 | .79 | 30 | 2.5 | 74 | 14 | 27 | .0 | 268 | 25 | 6.5 | 7.0 | 272 |
| July 18 | July 27 | 23 | 33 | 1 44 | 32 | 2 | 70 | 16 | 23 | .0 | 263 | 24 | 3.8 | 7.0 | 287 |
| July 28 | Aug. 6 | 340 | 234 | .68 | 42 | 10 | 49 | 13 | 24 | .0 | 175 | 21 | 3.5 | 6.0 | 240 |
| Aug. 7 | Aug. 16 | 53 | 38 | .72 | 19 | 1.0 | 56 | 9.2 | 23 | .0 | 169 | 18 | 4.8 | 5.0 | 184 |
| Aug. 17 | Aug. 26 | 46 | 24 | .52 | 24 | .7 | 49 | 12 | 26 | a8.0 | 212 | 19 | 2.0 | 4.0 | 228 |
| Aug. 27 | Sept. 6 | 40 | 24 | .60 | 26 | .14 | 61 | 14 | 23 | .0 | 220 | 24 | 1.8 | 5.0 | 230 |
| Sept. 7 | Sept. 18 | 21 | 19 | .90 | 24 | .03 | 58 | 13 | 25 | .0 | 220 | 24 | 1.0 | 7.2 | 235 |

a Abnormal; computed as $HCO_3$ in the average.

TABLE 172.—*Analyses of water from Neosho River at Emporia, Kans.*—Continued.

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1907. | 1907. | | | | | | | | | | | | | | |
| Sept. 20 | Sept. 30 | 27 | 25 | 0.92 | 18 | 0.08 | 58 | 15 | 25 | 0.0 | 225 | 21 | 0.4 | 5.7 | 222 |
| Oct. 1 | Oct. 11 | 74 | 66 | .89 | 19 | .40 | 50 | 14 | 21 | .0 | 185 | 22 | 1.9 | 6.5 | 199 |
| Oct. 12 | Oct. 21 | 38 | 17 | .45 | 11 | .10 | 62 | 14 | 27 | .0 | 250 | 26 | 1.8 | 6.5 | 232 |
| Oct. 28 | Nov. 6 | 48 | 38 | .79 | 16 | .24 | 51 | 14 | 18 | .0 | 182 | 20 | 6.0 | 6.0 | 196 |
| Nov. 7 | Nov. 16 | 32 | 22 | .69 | 18 | .10 | 66 | 12 | 17 | .0 | 193 | 21 | 1.8 | 8.5 | 198 |
| Nov. 17 | Nov. 25 | 15 | 1.6 | .11 | 18 | .14 | 54 | 14 | 23 | .0 | 195 | 24 | 1.2 | 6.5 | 213 |
| Nov. 26 | Dec. 5 | 11 | 4 | .36 | 17 | .18 | 60 | 14 | 32 | .0 | 210 | 28 | 1.3 | 8.5 | 241 |
| Mean | | 184 | 138 | .71 | 44 | 1.79 | 66 | 13 | 25 | .0 | 255 | 34 | 3.5 | 7.2 | 267 |
| Per cent of anhydrous residue | | ...... | ...... | ...... | 13.7 | .8 | 20.6 | 4.1 | 7.8 | 39.1 | ...... | 10.6 | 1.1 | 2.2 | .... |

NOTE.—Analyses from December 5, 1906, to February 4, 1907, and from March 17 to November 25, 1907, by F. W. Bushong; from February 5 to March 16, 1907, and from November 26 to December 5, 1907, by Archie J. Weith.

TABLE 173.—*Daily turbidity measurements of Neosho River at Emporia, Kans., and daily gage heights at Neosho Rapids, Kans.*

[Alva J. Smith and F. A. Bacon, observers.]

| Day. | 1904. | | | | | | | | | Turbidity, 1905. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August. | | September. | | October. | | November. | | December. | | | | | | | |
| | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | Gage heights. | Turbidity. | January. | February. | March. | April. | May. | June. | July. |
| 1 | 35 | 12.75 | 35 | 11.60 | 30 | 9.85 | 19 | 9.50 | 20 | 16 | 7 | 150 | 200 | 130 | 100 | 3,000 |
| 2 | 33 | 12.60 | 33 | 11.80 | 23 | 9.95 | 20 | 9.50 | 20 | 14 | 7 | 130 | 150 | 100 | 55 | 3,000 |
| 3 | 30 | 12.50 | 35 | 11.70 | 24 | 10.05 | 20 | 9.50 | 20 | 16 | 8 | 100 | 130 | 30 | 3,000 | 3,000 |
| 4 | 30 | 12.65 | 35 | 11.55 | 22 | 9.90 | 24 | 9.50 | 20 | 15 | 8 | 96 | 110 | 35 | 3,000 | 3,000 |
| 5 | 30 | 12.40 | 35 | 11.40 | 26 | 9.85 | 24 | 9.50 | 20 | 14 | 10 | 75 | 35 | 65 | 900 | 500 |
| 6 | 30 | 12.15 | 33 | 11.40 | 21 | 9.80 | 20 | ...... | 19 | 15 | 8 | 65 | 30 | 60 | 300 | 250 |
| 7 | 30 | 12.30 | 35 | 11.40 | 22 | 9.80 | 20 | ...... | 20 | 14 | 9 | 50 | 75 | 50 | 150 | 90 |
| 8 | 28 | 12.30 | 33 | 11.40 | 22 | 9.80 | 20 | ...... | 22 | 14 | 7 | 40 | 65 | 50 | 110 | 80 |
| 9 | 30 | 12.00 | 35 | 11.40 | 22 | 9.80 | 20 | ...... | 20 | 16 | 7 | 40 | 55 | 40 | 95 | 250 |
| 10 | 40 | 12.00 | 40 | 11.40 | 21 | 9.80 | 20 | ...... | 20 | 17 | 7 | 35 | 55 | 40 | 80 | 1,500 |
| 11 | 28 | 12.15 | 60 | 9.90 | 21 | 9.80 | 20 | ...... | 20 | 14 | 7 | 30 | 55 | 65 | 80 | 300 |
| 12 | 40 | 12.05 | 42 | 9.90 | 18 | 9.80 | 20 | ...... | 20 | 14 | 7 | 23 | 55 | 50 | 60 | 150 |
| 13 | 30 | 12.00 | 60 | 9.80 | 18 | 9.80 | 20 | ...... | 20 | 15 | 7 | 23 | 45 | 60 | 55 | 100 |
| 14 | 35 | 11.95 | 60 | 9.80 | 17 | 9.80 | 22 | ...... | 20 | 15 | 7 | 23 | 45 | 65 | 45 | 75 |
| 15 | 33 | 11.90 | 45 | 10.05 | 16 | 9.70 | 24 | ...... | 20 | 17 | 7 | 20 | 55 | 55 | 40 | 45 |
| 16 | 35 | 11.90 | 35 | 9.90 | 17 | 9.65 | 26 | ...... | 20 | 17 | 7 | 20 | 55 | 50 | 35 | 40 |
| 17 | 33 | 11.90 | 35 | 9.90 | 15 | 9.60 | 30 | ...... | 21 | 14 | 7 | 26 | 50 | 45 | 35 | 40 |
| 18 | 35 | 11.90 | 35 | 9.80 | 17 | 9.60 | 30 | ...... | 18 | 14 | 7 | 50 | 50 | 40 | 35 | 40 |
| 19 | 40 | 11.90 | 33 | 9.80 | 19 | 9.60 | 35 | ...... | 17 | 17 | 7 | 60 | 45 | 40 | 24 | 35 |
| 20 | 35 | 11.90 | 30 | 9.80 | 18 | 9.60 | 35 | ...... | 18 | 17 | 7 | 70 | 45 | 35 | 26 | 35 |
| 21 | 35 | 11.90 | 30 | 9.80 | 19 | 9.60 | 35 | ...... | 17 | 17 | 7 | 40 | 45 | 35 | 60 | 30 |
| 22 | 45 | 12.15 | 35 | 9.80 | 17 | 9.60 | 30 | ...... | 17 | 15 | 10 | 35 | 45 | 35 | 35 | 35 |
| 23 | 45 | 13.75 | 33 | 9.80 | 20 | 9.50 | 28 | ...... | 14 | 16 | 70 | 40 | 40 | 40 | 30 | 30 |
| 24 | 40 | 13.80 | 30 | 9.90 | 20 | 9.50 | 26 | ...... | 15 | 15 | 200 | 40 | 45 | 45 | 30 | 30 |
| 25 | 38 | 12.50 | 28 | 9.90 | 19 | 9.50 | 24 | ...... | 17 | 16 | 200 | 45 | 55 | 55 | 30 | 28 |
| 26 | 40 | 11.90 | 28 | 9.90 | 20 | 9.50 | 24 | ...... | 17 | 13 | 200 | 45 | 500 | 55 | 28 | 26 |
| 27 | 40 | 11.90 | 28 | 9.90 | 22 | 9.50 | 24 | ...... | 18 | 11 | 200 | 55 | 250 | 75 | 28 | 26 |
| 28 | 40 | 11.80 | 26 | 9.80 | 18 | 9.50 | 24 | ...... | 18 | 12 | 180 | 500 | 100 | 70 | 28 | 1,500 |
| 29 | 35 | 11.75 | 26 | 9.80 | 20 | 9.50 | 24 | ...... | 17 | 15 | ...... | 3,000 | 130 | 130 | 60 | 350 |
| 30 | 26 | 11.60 | 30 | 9.80 | 18 | 9.50 | 24 | ...... | 17 | 7 | ...... | 500 | 120 | 130 | 3,000 | 300 |
| 31 | 26 | 11.60 | .... | ...... | 18 | 9.50 | .... | ...... | 18 | 7 | ...... | 230 | ..... | 150 | ...... | 800 |
| Mean | 34 | ...... | 36 | ...... | 20 | ...... | 24 | ...... | 19 | 14 | 43 | 182 | 91 | 62 | 385 | 603 |

TABLE 174.—*Turbidity of daily samples from Neosho River at Emporia, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | ...... | 30 | 8 | 2,436 | 48 | 45 | 45 | 160 | 510 | 45 | 10 | 45 | 8 |
| 2 | ...... | 13 | ...... | 3,000 | 65 | 38 | 43 | ...... | 320 | 24 | 18 | 45 | 10 |
| 3 | ...... | 7 | 5 | 1,902 | 62 | 50 | 32 | 80 | 12 | 30 | 45 | 50 | 15 |
| 4 | ...... | 4 | 6 | 970 | 42 | 26 | 52 | 85 | 200 | 24 | 165 | 40 | ...... |
| 5 | 52 | 6 | 2 | 500 | 45 | 34 | 38 | 90 | 130 | 22 | 100 | 70 | 24 |
| 6 | 38 | 20 | 4 | 190 | 38 | 50 | 68 | 68 | 110 | 16 | 100 | 60 | ...... |
| 7 | 32 | 8 | 5 | 80 | 65 | 34 | 35 | 65 | 65 | 12 | 90 | 30 | ...... |
| 8 | 37 | 8 | 8 | 43 | 60 | 38 | 6,000 | 55 | 65 | 10 | 80 | 24 | ...... |
| 9 | 30 | 9 | 6 | 50 | 68 | 36 | 2,472 | 65 | 65 | 18 | 75 | 36 | ...... |
| 10 | 24 | 3 | 550 | 3,300 | 48 | 35 | 500 | 50 | 45 | 20 | 60 | 50 | ...... |
| 11 | 30 | 5 | 650 | 2,472 | 55 | 32 | 900 | 65 | 48 | 36 | 70 | 40 | ...... |
| 12 | 25 | 7 | 600 | 2,000 | 40 | 38 | 220 | 82 | 35 | 40 | 50 | 32 | ...... |
| 13 | 20 | 14 | 473 | 380 | 50 | 38 | 210 | 120 | 44 | 30 | 70 | 45 | ...... |
| 14 | 24 | 15 | 430 | 205 | 50 | 34 | 200 | 70 | 50 | 24 | 50 | 24 | ...... |
| 15 | 24 | 18 | 240 | 105 | 50 | 34 | 110 | 46 | 55 | 20 | 45 | 24 | ...... |
| 16 | 20 | 5 | 110 | 65 | 38 | 35 | 100 | 32 | 62 | 16 | 12 | 16 | ...... |
| 17 | 24 | 16 | 65 | 36 | 34 | 22 | 45 | 26 | 55 | 15 | 32 | 16 | ...... |
| 18 | 15 | 12 | 60 | 32 | 27 | 22 | 55 | 14 | 55 | 12 | 24 | 18 | ...... |
| 19 | 12 | 36 | 58 | 43 | 26 | 34 | 80 | 40 | 48 | ...... | 30 | 18 | ...... |
| 20 | 5 | 4,200 | 28 | 32 | 24 | 65 | 50 | 55 | 65 | 16 | 30 | 16 | ...... |
| 21 | 5 | 1,520 | 30 | 35 | 27 | 68 | 105 | 45 | 38 | 12 | 40 | 15 | ...... |
| 22 | 8 | 830 | 24 | 24 | ...... | 55 | 80 | 12 | 20 | 45 | ...... | 10 | ...... |
| 23 | 12 | 308 | 14 | 36 | 22 | 35 | 500 | 24 | 27 | 24 | ...... | 8 | ...... |
| 24 | 12 | 45 | 14 | 45 | 36 | 42 | 140 | 14 | 43 | 20 | ...... | 24 | ...... |
| 25 | 15 | 90 | 16 | 42 | 50 | 48 | 200 | 26 | 45 | 18 | ...... | 12 | ...... |
| 26 | 12 | 28 | 11 | 42 | 24 | 60 | 5,335 | 18 | 60 | 40 | ...... | 8 | ...... |
| 27 | 7 | 16 | 11 | 45 | 50 | 70 | 3,060 | 26 | 55 | 45 | ...... | 8 | ...... |
| 28 | 10 | 13 | 34 | 45 | 43 | ...... | 1,530 | 45 | 45 | 24 | 50 | 8 | ...... |
| 29 | 10 | 8 | ...... | 43 | 32 | 50 | 500 | 562 | 50 | 20 | 36 | 10 | ...... |
| 30 | 19 | 16 | ...... | 27 | 32 | 48 | 460 | 765 | 60 | 30 | 40 | 12 | ...... |
| 31 | 14 | 13 | ...... | 48 | ...... | 57 | ...... | 732 | 65 | ...... | 45 | ...... | ...... |
| Mean | 20 | 236 | 128 | 589 | 43 | 42 | 792 | 118 | 82 | 24 | 55 | 27 | 14 |

NOTE.—Turbidities of more than 50 were determined with a Jackson turbidimeter, and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

TABLE 175.—*Analyses of water from Neosho River at Oswego, Kans.*

[Drainage area, 5,230 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. | Mean gage height (feet). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | | |
| Dec. 11 | Dec. 20 | 75 | 34 | 0.45 | 19 | 2.4 | 59 | 11 | 27 | 0.0 | 190 | 65 | 3.1 | 11 | 282 | 0.8 |
| Dec. 21 | Dec. 31 | 13 | 10 | .77 | 17 | .40 | 103 | 21 | 24 | .0 | 324 | 129 | 3.8 | 14 | 453 | .6 |
| 1907. | 1907. | | | | | | | | | | | | | | | |
| Jan. 1 | Jan. 16 | 108 | 87 | .80 | 17 | 2.4 | 86 | 16 | 24 | .0 | 235 | 98 | 4.6 | 16 | 372 | 1.3 |
| Jan. 17 | Jan. 26 | 730 | 645 | .88 | 38 | 4.0 | 30 | 1.5 | 29 | .0 | 80 | 27 | 7.9 | 3.8 | 165 | 18.1 |
| Jan. 27 | Feb. 5 | 373 | 286 | .77 | 39 | 3.0 | 67 | 3.9 | 22 | .0 | 202 | 45 | 5.3 | 7.2 | 280 | 2.7 |
| Feb. 6 | Feb. 15 | 31 | 30 | .97 | 16 | .12 | 83 | 15 | 30 | .0 | 326 | 62 | 3.1 | 10 | 333 | 1.5 |
| Feb. 16 | Feb. 25 | 84 | 62 | .74 | 56 | .10 | 97 | 12 | 29 | .0 | 332 | 65 | 3.5 | 8.8 | 410 | 1.3 |
| Feb. 26 | Mar. 7 | 618 | 495 | .80 | 28 | .32 | 82 | 13 | 28 | a 3.3 | 227 | 74 | 3.2 | 8.2 | 348 | 2.7 |
| Mar. 8 | Mar. 19 | 1,073 | 752 | .70 | 18 | .08 | 56 | 12 | 45 | .0 | 180 | 46 | 3.7 | 4.6 | 245 | 4.0 |
| Mar. 22 | Apr. 2 | 368 | 307 | .83 | 16 | 4.0 | 70 | 12 | 24 | .0 | 253 | 47 | 2.2 | 7.6 | 303 | 1.7 |
| Apr. 3 | Apr. 13 | 170 | 126 | .74 | 17 | 5.0 | 70 | 13 | 24 | .0 | 238 | 52 | 2.1 | 8.5 | 293 | 1.1 |
| Apr. 14 | Apr. 23 | 36 | 28 | .78 | 2.0 | .7 | 81 | 14 | 23 | .0 | 275 | 77 | .6 | 12 | 328 | .7 |
| Apr. 25 | May 4 | 315 | 350 | 1.11 | 7.2 | 2.4 | 65 | 18 | 23 | .0 | 209 | 67 | 3.0 | 11 | 281 | 2.8 |
| May 5 | June 1 | 404 | 391 | .97 | 21 | 5 | 61 | 3.2 | 26 | .0 | 172 | 56 | 5.5 | 8 | 257 | ..... |
| June 2 | June 12 | 289 | 310 | 1.07 | 10 | 2.0 | 89 | 15 | 25 | .0 | 295 | 67 | 2.6 | 10 | 359 | 1.3 |
| June 13 | June 22 | 140 | 108 | .77 | 21 | 3 | 71 | 20 | 27 | a12 | 230 | 57 | 4 | 9 | 303 | 1.1 |
| June 24 | July 5 | 835 | 679 | .81 | 22 | 3.5 | 43 | 9.2 | 25 | .0 | 145 | 32 | 6.0 | 6.0 | 205 | 7.3 |
| July 8 | July 17 | 73 | 110 | 1.51 | 28 | 1.8 | 67 | 18 | 25 | .0 | 242 | 42 | 5.5 | 8 | 273 | 1.1 |
| July 18 | July 31 | 33 | 42 | 1.27 | 20 | 1.5 | 72 | 18 | 26 | a14 | 115 | 52 | .6 | 8 | 281 | .6 |
| Aug. 1 | Sept. 2 | 20 | 15 | .75 | 20 | .04 | 80 | 19 | 26 | .0 | 263 | 55 | 1.7 | 9 | 310 | ..... |
| Sept. 3 | Sept. 15 | 27 | 20 | .74 | ..... | .05 | 68 | 18 | 26 | .0 | 232 | 52 | 1.4 | 10 | 287 | .3 |
| Sept. 18 | Oct. 2 | 29 | 39 | 1.35 | 13 | .10 | 68 | 27 | 42 | .0 | 185 | 117 | Trace. | 13 | 334 | .0 |
| Oct. 3 | Oct. 19 | 15 | 7.0 | .47 | 15 | .03 | 83 | 24 | 29 | .0 | 255 | 88 | .6 | 11 | 346 | .5 |
| Oct. 20 | Nov. 5 | 45 | 35 | .78 | 14 | .14 | 78 | 21 | 28 | .0 | 220 | 106 | .5 | 13 | 300 | .6 |
| Nov. 7 | Nov. 18 | 37 | 15 | .40 | 15 | .02 | 57 | 13 | 23 | .0 | 192 | 50 | 1.5 | 11 | 240 | .7 |
| Nov. 19 | Nov. 28 | 66 | 43 | .65 | 10 | .20 | 58 | 15 | 27 | .0 | 198 | 62 | 1.1 | 9.5 | 247 | .9 |
| Dec. 2 | Dec. 9 | 70 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | .0 | 160 | ..... | .9 | 13 | ..... | .3 |
| Mean | | 225 | 194 | .84 | 20 | 1.03 | 71 | 15 | 27 | .0 | 223 | 65 | 2.9 | 9.7 | 304 | ..... |
| Per cent of anhydrous residue | | ..... | ..... | ..... | 6.2 | .7 | 22.0 | 4.6 | 8.4 | 34.0 | ..... | 20.2 | .9 | 3.0 | ..... | ..... |

*a* Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 11, 1906, to February 5, 1907, and from March 22 to December 9, 1907, by F. W. Bushong; from February 15 to March 19, 1907, by Archie J. Weith.

TABLE 176.—*Daily turbidity measurements of Neosho River at Oswego, Kans.*

[Nelie Nafus, observer.]

| Day. | Turbidity, 1904. | | | | | | | | | Turbidity, 1905. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June. | | July. | | | | | | | | | | | | | |
| | Measurements. | Gage heights at Humboldt, Kans. | Measurements. | Gage heights at Humboldt, Kans. | August. | September. | October. | November. | December. | January. | February. | March. | April. | May. | June. | July. |
| 1 | 1,500 | 21.00 | 1,200 | 22.80 | 55 | 80 | 28 | 30 | 26 | 19 | (a) | 800 | 1,200 | 70 | 450 | 250 |
| 2 | 1,500 | 22.95 | 1,000 | 21.80 | .... | 75 | 28 | 30 | 24 | 19 | .... | 800 | 2,000 | 65 | 400 | 250 |
| 3 | 1,000 | 28.15 | 1,000 | 13.90 | .... | 75 | 28 | 30 | 24 | 19 | .... | 600 | 2,000 | 60 | 400 | 1,000 |
| 4 | 800 | 28.90 | 1,000 | 11.65 | .... | 70 | 28 | 30 | 24 | 19 | .... | 350 | 2,000 | 60 | 350 | 1,000 |
| 5 | 800 | 27.60 | 800 | 13.33 | .... | 65 | 30 | 30 | 22 | 19 | .... | 350 | 2,000 | 50 | 300 | 1,000 |
| 6 | 800 | 27.30 | 800 | 24.20 | .... | 60 | 30 | 30 | 22 | 19 | .... | 800 | 1,800 | 45 | 500 | 1,500 |
| 7 | 500 | 28.30 | 800 | 26.75 | .... | 58 | 28 | 30 | 22 | 19 | .... | 800 | 1,800 | 40 | 600 | 1,500 |
| 8 | 500 | 27.40 | 600 | 28.50 | .... | 55 | 28 | 30 | 21 | 19 | .... | 800 | 1,700 | 35 | 500 | 2,000 |
| 9 | 500 | 25.95 | 600 | 29.25 | .... | 50 | 28 | 29 | 22 | 19 | .... | 500 | 1,600 | 35 | 550 | 2,000 |
| 10 | 500 | 24.50 | 600 | 30.50 | 55 | 45 | 30 | 29 | 22 | 19 | .... | 400 | 1,500 | 30 | 450 | 2,000 |
| 11 | 500 | 18.35 | 500 | 29.75 | 55 | 45 | 32 | 28 | 21 | 19 | 19 | 350 | 1,500 | 110 | 400 | 2,000 |
| 12 | 500 | 13.25 | 500 | 28.70 | 50 | 42 | 32 | 28 | 21 | 19 | 19 | 350 | 1,400 | 200 | 375 | 2,500 |
| 13 | 500 | 15.70 | 500 | 27.25 | 47 | 42 | 32 | 27 | 20 | 19 | 19 | 300 | 1,200 | 200 | 200 | 2,500 |
| 14 | 500 | 17.10 | 500 | 26.10 | 45 | 38 | 32 | 27 | 20 | (b) | 19 | 250 | 1,000 | 250 | 150 | 2,000 |
| 15 | 600 | 13.15 | 500 | 25.05 | 45 | 38 | 32 | 27 | 20 | .... | 19 | 200 | 800 | 300 | 100 | 1,500 |
| 16 | 800 | 15.75 | 400 | 22.95 | 45 | 35 | 32 | 27 | 20 | .... | 19 | 180 | 800 | 350 | 180 | 1,000 |
| 17 | 1,000 | 18.00 | 400 | 12.00 | 45 | 35 | 30 | 27 | 19 | .... | 19 | 150 | 650 | 400 | 250 | 800 |
| 18 | 1,200 | 13.20 | 400 | 7.00 | 140 | 33 | 30 | 27 | 19 | .... | 19 | 400 | 500 | 400 | 200 | 600 |
| 19 | 1,500 | 12.80 | 500 | .... | 110 | 33 | 40 | 27 | 19 | .... | 19 | 500 | 350 | 350 | 200 | 500 |
| 20 | 1,500 | 15.10 | 600 | .... | 150 | 30 | 35 | 28 | 18 | .... | 19 | 800 | 250 | 300 | 180 | 300 |
| 21 | 1,500 | 15.90 | 700 | .... | 180 | 30 | 32 | 28 | 18 | .... | 19 | 800 | 130 | 250 | 600 | 200 |
| 22 | 1,200 | 14.00 | 700 | .... | 350 | 30 | 32 | 28 | 18 | .... | 19 | 800 | 100 | 200 | 800 | 180 |
| 23 | 1,200 | 9.20 | 800 | .... | 500 | 500 | 30 | 28 | 19 | .... | 19 | 500 | 80 | 100 | 650 | 150 |
| 24 | 1,000 | 6.00 | 800 | .... | 400 | 350 | 30 | 28 | 19 | .... | 19 | 400 | 70 | 90 | 500 | 100 |
| 25 | 1,000 | 14.90 | 700 | .... | 400 | 170 | 30 | 28 | 18 | .... | 1,000 | 350 | 55 | 80 | 400 | 80 |
| 26 | 1,000 | 23.05 | 600 | .... | 400 | 80 | 30 | 28 | 18 | .... | 1,000 | 300 | 40 | 75 | 350 | 80 |
| 27 | 1,200 | 25.95 | 500 | .... | 350 | 40 | 30 | 28 | 18 | .... | 800 | 250 | 40 | 70 | 400 | 75 |
| 28 | 1,200 | 24.65 | 500 | .... | 250 | 35 | 30 | 28 | 18 | .... | 800 | 200 | 35 | 65 | 200 | 60 |
| 29 | 1,200 | 23.40 | 400 | .... | 180 | 32 | 30 | 28 | 19 | .... | .... | 130 | 30 | 500 | 180 | 80 |
| 30 | 1,200 | 23.10 | 400 | .... | 100 | 30 | 30 | 28 | 19 | .... | .... | 130 | 70 | 450 | 100 | 250 |
| 31 | .... | .... | 300 | .... | 80 | .... | 30 | .... | 19 | .... | .... | 800 | .... | 450 | .... | 800 |
| Mean | 957 | .... | 632 | .... | 269 | 77 | 30 | 28 | 20 | 19 | 215 | 462 | 890 | 183 | 364 | 911 |

a From February 1 to 10, inclusive, frozen.

b From January 14 to 31, inclusive, frozen.

TABLE 177.—*Turbidity of daily samples from Neosho River at Oswego, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | ...... | 3 | 245 | 34 | 1,000 | 966 | 160 | 1,360 | 18 | 18 | 16 | 36 | ...... |
| 2 | ...... | 3 | 110 | 24 | 933 | 473 | 155 | 53 | 14 | 40 | 15 | 30 | 60 |
| 3 | ...... | 65 | 140 | 180 | 500 | 385 | ...... | 632 | ...... | 45 | 10 | 90 | ...... |
| 4 | ...... | 137 | 38 | 1,124 | 420 | 350 | 40 | 510 | 15 | 50 | 10 | 120 | ...... |
| 5 | ...... | 60 | 27 | 1,530 | 265 | 473 | 65 | 370 | 15 | 40 | 15 | 30 | ...... |
| 6 | ...... | 42 | 25 | 1,866 | 105 | 365 | 27 | ...... | 22 | ...... | 16 | ...... | 90 |
| 7 | ...... | 36 | 14 | 1,360 | 75 | 562 | 65 | ...... | 24 | ...... | ...... | 16 | 80 |
| 8 | ...... | 42 | 28 | 1,000 | 48 | 632 | 28 | 85 | 12 | 16 | 24 | 30 | 50 |
| 9 | ...... | 30 | 20 | 1,000 | 85 | 350 | 40 | 115 | ...... | 12 | 8 | 36 | 70 |
| 10 | ...... | ...... | 24 | 732 | 90 | ...... | 65 | 45 | 27 | ...... | ...... | 32 | ...... |
| 11 | 95 | ...... | 9 | 732 | 105 | 317 | 1,200 | 48 | ...... | 18 | 18 | 70 | ...... |
| 12 | 70 | ...... | 27 | ...... | ...... | 220 | 1,200 | 130 | ...... | 18 | ...... | 50 | ...... |
| 13 | 75 | ...... | 27 | ...... | 55 | ...... | 340 | 110 | ...... | 16 | ...... | 24 | ...... |
| 14 | 70 | ...... | 60 | 1,932 | 36 | ...... | 150 | 28 | ...... | 30 | 12 | 15 | ...... |
| 15 | 75 | 550 | 80 | 2,100 | 48 | ...... | 140 | 26 | ...... | 20 | ...... | 24 | ...... |
| 16 | 55 | 110 | 70 | 1,000 | 27 | 833 | 120 | 55 | ...... | ...... | ...... | ...... | ...... |
| 17 | 40 | 700 | 120 | 933 | 38 | ...... | 100 | 85 | ...... | ...... | 10 | 45 | ...... |
| 18 | 40 | 650 | 100 | 700 | 23 | ...... | 55 | 120 | ...... | 50 | 24 | 30 | ...... |
| 19 | 2 | 268 | 130 | 600 | 27 | ...... | 70 | 34 | ...... | 18 | 15 | 36 | ...... |
| 20 | 5 | 930 | 120 | ...... | 62 | ...... | 45 | ...... | ...... | 15 | 16 | 40 | ...... |
| 21 | 16 | 900 | 105 | ...... | 26 | ...... | 80 | ...... | ...... | ...... | ...... | 36 | ...... |
| 22 | 14 | 970 | 60 | 412 | 36 | ...... | 300 | 34 | ...... | ...... | 36 | 36 | ...... |
| 23 | 15 | 700 | 50 | 190 | 38 | ...... | ...... | 36 | ...... | ...... | 50 | 100 | ...... |
| 24 | 13 | 650 | 43 | 385 | ...... | ...... | 532 | ...... | ...... | ...... | 24 | 200 | ...... |
| 25 | 16 | 833 | 36 | 120 | 26 | ...... | 1,732 | ...... | ...... | 32 | ...... | 190 | ...... |
| 26 | 15 | 680 | 17 | ...... | 55 | ...... | ...... | 9 | ...... | ...... | ...... | 24 | ...... |
| 27 | 14 | 732 | 22 | 115 | 35 | ...... | 933 | 18 | ...... | 30 | ...... | 10 | ...... |
| 28 | 11 | 866 | 22 | ...... | 40 | ...... | 1,226 | 24 | ...... | 45 | ...... | 185 | ...... |
| 29 | 11 | 666 | ...... | 110 | 35 | ...... | ...... | 36 | ...... | 40 | 36 | ...... | ...... |
| 30 | 9 | 532 | ...... | 110 | 800 | ...... | 1,000 | 10 | ...... | 24 | ...... | ...... | ...... |
| 31 | 7 | 370 | ...... | 305 | ...... | 130 | ...... | 13 | ...... | ...... | 24 | ...... | ...... |
| Mean | 32 | 443 | 63 | 744 | 180 | 466 | 380 | 160 | 18 | 29 | 20 | 59 | 70 |

NOTE.—Turbidities above 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

TABLE 178.—*Assays of water from Neosho River and its tributaries, exclusive of Spring River.*

[By Edward Bartow. Quantities in parts per million.]

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | |
| 1 | July 29 | Neosho River above Slough Creek, 4 miles northwest of Council Grove | 0.0 | 0.0 | 118 | Trace. | 4 |
| 2 | ...do.... | Slough Creek, 4½ miles north and 2 miles west of Council Grove | 2.0 | .0 | 124 | Trace. | 4 |
| 3 | ...do.... | East Branch Neosho River, 4½ miles northwest of Council Grove | Trace. | .0 | 116 | Trace. | 4 |
| 4 | ...do.... | Neosho River at dam, Council Grove | 1.5 | .0 | 113 | Trace. | 4 |
| 5 | ...do.... | Elm Creek, south of Council Grove | .0 | .0 | 275 | Trace. | 9 |
| 6 | ...do.... | Four Mile Creek, 2 miles east and 3 miles south of Council Grove | .0 | .0 | 257 | Trace. | 6 |
| 7 | ...do.... | Big John Creek, 4 miles southeast of Council Grove | .0 | .0 | 325 | Trace. | 6 |
| 8 | ...do.... | Rock Creek, ½ mile northwest of Dunlap | .0 | .0 | 240 | Trace. | 9 |
| 9 | July 28 | Neosho River, 1½ miles north of Emporia | .0 | .0 | 124 | Trace. | 6 |
| 10 | ...do.... | Cottonwood River above South Cottonwood River, 3 miles west and 1 mile north of Marion | .0 | .0 | 156 | 150 | 9 |
| 11 | ...do.... | South Cottonwood River, 3 miles west of Marion | .0 | .0 | 257 | 492 | 12 |
| 12 | ...do.... | Cottonwood River, at bridge west of Atchison, Topeka & Santa Fe Ry. depot, Marion | .0 | .0 | 80 | 362 | 12 |
| 13 | ...do.... | Clear Creek, ½ mile north of Marion | .0 | .0 | 332 | 492 | 16 |
| 14 | ...do.... | Lula Brook, 2 miles north and ½ mile west of Marion | .0 | .0 | 249 | 238 | 14 |
| 15 | ...do.... | Spring Branch, 3 miles south of Marion | .0 | .0 | 332 | 150 | 16 |
| 16 | ...do.... | Cottonwood River, 1 mile north of Florence | Trace. | 12.0 | 289 | 431 | 16 |

TABLE 178.—*Assays of water from Neosho River and its tributaries, exclusive of Spring River*—Continued.

| No. | Date. | Stream and place. | Iron (Fe). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). |
|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | |
| 17 | July 27 | Doyle Creek at Peabody | 0.0 | 0.0 | 306 | (a) | 34 |
| 18 | July 28 | Doyle Creek, south of Florence | .0 | .0 | 322 | 431 | 24 |
| 19 | ...do..... | Cottonwood River, east of Elmdale | .0 | .0 | 300 | 138 | 12 |
| 20 | ...do..... | Middle Creek at Elmdale | .0 | .0 | 282 | Trace. | 9 |
| 21 | ...do..... | Diamond Creek, 1½ miles north of Elmdale | .0 | .0 | 163 | Trace. | 6 |
| 22 | ...do..... | Buckeye Creek, ½ mile east of Cottonwood Falls | .5 | .0 | 311 | Trace. | 9 |
| 23 | ...do..... | South Fork of Cottonwood River, 4 miles east of Cottonwood Falls | .0 | .0 | 290 | Trace. | 12 |
| 24 | ...do..... | Cottonwood River below mill dam at Emporia | .0 | 12.0 | 305 | 160 | 14 |
| 25 | July 26 | Neosho River at Burlington | Trace. | .0 | 306 | 53 | 11 |
| 26 | July 25 | Wolf Creek, 2½ miles east and 1¾ miles south of bridge at Burlington | .5 | .0 | 197 | 35 | 6 |
| 27 | ...do..... | Long Creek, 4½ miles north and ½ mile west of Leroy | Trace. | .0 | 185 | Trace. | 6 |
| 28 | ...do..... | Turkey Creek, 2 miles south and 4 miles west of Leroy | .5 | .0 | 128 | Trace. | 6 |
| 29 | ...do..... | Big Creek, 2½ miles west of Leroy | .5 | .0 | 202 | Trace. | 10 |
| 30 | ...do..... | Neosho River at Leroy | .0 | Trace. | 284 | 43 | 12 |
| 31 | ...do..... | Crooked Creek, 1 mile east of Leroy | 4.0 | .0 | 134 | Trace. | 14 |
| 32 | June 30 | Deer Creek, northwest of Iola | .0 | .0 | 199 | Trace. | 10 |
| 33 | July 21 | Neosho River at waterworks, Iola | .0 | .0 | 274 | 31 | 12 |
| 34 | June 30 | Elm Creek, 2 miles south of Laharpe | Trace. | .0 | 202 | Trace. | 30 |
| 35 | July 20 | Elm Creek above outfall of Iola sewer, and at dam of Iola Portland Cement Co. | .0 | .0 | 111 | 113 | 16 |
| 36 | ...do..... | Elm Creek, ½ mile below Iola sewer outfall | .0 | .0 | 329 | 53 | 89 |
| 37 | June 30 | Rock Creek at power plant of electric railway, Iola | Trace. | .0 | 160 | 37 | 4 |
| 38 | July 21 | Neosho River at dam at Humboldt | .0 | .0 | 270 | 35 | 12 |
| 39 | July 24 | Owl Creek, 7 miles east and 2 miles south of Yates Center | 1.0 | .0 | 138 | Trace. | 6 |
| 40 | ...do..... | South Owl Creek, 7 miles east and 4 miles south of Yates Center | 4.0 | .0 | 116 | Trace. | 9 |
| 41 | ...do..... | Cherry Creek,[b] 6 miles east of Yates Center | 2.0 | .0 | 90 | Trace. | 6 |
| 42 | July 23 | Owl Creek, 1½ miles west of Humboldt | Trace. | .0 | 112 | Trace. | 9 |
| 43 | July 21 | Coal Creek, south of Humboldt | .0 | .0 | 270 | Trace. | 30 |
| 44 | ...do..... | Village Creek, 1 mile north of Chanute | .0 | .0 | 217 | Trace. | 16 |
| 45 | ...do..... | Lake north of Chanute | .0 | .0 | 138 | Trace. | 12 |
| 46 | July 22 | Neosho River at waterworks, Chanute | .0 | .0 | 252 | 40 | 12 |
| 47 | July 21 | Turkey Creek, 3 miles south and 1 mile east of Chanute | .0 | .0 | 83 | Trace. | 9 |
| 48 | ...do..... | Big Creek, 3 miles north and 1½ miles west of Shaw | .0 | .0 | 217 | Trace. | 12 |
| 49 | July 22 | Neosho River at Shaw | .0 | .0 | 244 | Trace. | 14 |
| 50 | ...do..... | Elk Creek, 1 mile west of Shaw | .0 | .0 | 316 | Trace. | 9 |
| 51 | ...do..... | Canville Creek, 1 mile east of Shaw | .5 | .0 | 160 | Trace. | 6 |
| 52 | July 19 | Neosho River at Erie | .0 | .0 | 206 | Trace. | 6 |
| 53 | ...do..... | Flat Rock Creek, ½ mile south and ½ mile east of Erie | .0 | .0 | 157 | Trace. | 6 |
| 54 | July 16 | Neosho River at Oswego | .0 | .0 | 224 | Trace. | 7 |
| 55 | July 3 | Lightning Creek, northwest of Girard[c] | .5 | .0 | 68 | Trace. | 10 |
| 56 | July 15 | Lightning Creek, northeast of Oswego | .0 | .0 | 160 | 68 | 7 |
| 57 | July 10 | Tributary of Cherry Creek, 1 mile north of Scammon[d] | 288.0 | .0 | Acid. | (a) | 50 |
| 58 | July 15 | Cherry Creek, 6 miles east of Oswego | .0 | .0 | 15 | 157 | 7 |
| 59 | July 19 | Labette Creek at waterworks, Parsons | .0 | .0 | 112 | Trace. | 5 |
| 60 | ...do..... | Labette Creek, 1 mile below sewers, Parsons | .0 | .0 | 151 | 47 | 30 |
| 61 | ...do..... | Little Labette Creek, south of Parsons | Trace. | .0 | 132 | Trace. | 6 |
| 62 | ...do..... | Labette Creek below Little Labette Creek, Parsons | .0 | .0 | 152 | 41 | 16 |
| 63 | ...do..... | Bachelor Creek, 3½ miles south of Parsons | .0 | .0 | 123 | 36 | 6 |
| 64 | July 17 | Labette Creek, 2 miles west of Oswego | .0 | .0 | 155 | 37 | 9 |
| 65 | ...do..... | Hackberry Creek, 3 miles south and 5½ miles west of Oswego | .0 | .0 | 165 | Trace. | 7 |
| 66 | ...do..... | Deer Creek, 3 miles south and 5 miles west of Oswego | Trace. | .0 | 130 | Trace. | 7 |
| 67 | ...do..... | Hackberry Creek below Deer Creek, west of Oswego | .0 | .0 | 165 | Trace. | 9 |
| 68 | ...do..... | Labette Creek, 3 miles north of Chetopa | .5 | .0 | 133 | 36 | 9 |
| 69 | ...do..... | Neosho River at Chetopa | Trace. | .0 | 243 | Trace. | 9 |

a $SO_4$ greater than 626.
b Local name, North Owl Creek.
c By H. N. Parker.
d Contains coal-mine drainage.

NOTE.—Trace in sulphate column means less than 35 parts per million; trace in iron column means less than 0.5 parts per million.

TABLE 179.—*Analyses of water from Neosho River and its tributaries in Kansas.*

[Parts per million.]

| No. | Date. | Source. | Analyst. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$).[a] | Sulphate ($SO_4$). | Chlorine (Cl). | Organic and volatile. | Total solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ........ | Neosho River, at Council Grove | Missouri Pacific Ry | 13 | 1.3 | 80 | 14 | 18 | 138 | 49 | 9 | 17 | 341 |
| 2 | ........ | Pond, at Bushong | do | 3.4 | 1.2 | 31 | 12 | 4.7 | 55 | 34 | 7.3 | 20 | 170 |
| 3 | Nov. 15, 1902 | Neosho River, at Emporia | Kennicott Water Softener Co | 21 | 1 | 113 | 15 | 6.1 | 184 | 34 | 12 | ........ | ........ |
| 4 | Sept., 1908 | Pond, at Peabody | Chicago, Rock Island & Pacific Ry. | ........ | [b]9.4 | 48 | 20 | 7 | 83 | 48 | 11 | ........ | 226 |
| 5 | Apr. 5, 1901 | Spring Creek, at Peabody | Atchison, Topeka & Santa Fe Ry. | ........ | ........ | 429 | 78 | 36 | 162 | 690 | 58 | 180 | 1,645 |
| 6 | do | Doyle Creek, at Peabody | do | ........ | ........ | 505 | 90 | 10 | 135 | 897 | 16 | 200 | 1,870 |
| 7 | ........ | do | do | ........ | ........ | 343 | 72 | 45 | 259 | 720 | 55 | 399 | ........ |
| 8 | ........ | Chicago, Rock Island & Pacific Ry. reservoir, southeast of Peabody. | do | 12 | 7.2 | 53 | 21 | 10 | 126 | 17 | 9.3 | 60 | 319 |
| 9 | Dec. 11, 1902 | Cottonwood River, at Marion | Chicago, Rock Island & Pacific Ry. | 18 | 6.4 | 101 | 29 | 14 | 157 | 107 | 22 | ........ | ........ |
| 10 | Sept., 1908 | do | do | ........ | [b]5 | 174 | 44 | 17 | 166 | 350 | 7.8 | ........ | 764 |
| 11 | Oct. 1, 1897 | Doyle and Spring Creeks, at Florence. | Atchison, Topeka & Santa Fe Ry. | 29 | ........ | 139 | 43 | 28 | 85 | 268 | 24 | 127 | 748 |
| 12 | Sept. 27, 1902 | Cottonwood River, at Clements | do | 24 | .8 | 62 | 11 | 13 | 77 | 77 | 12 | ........ | ........ |
| 13 | Sept. 19, 1902 | Cottonwood River, at Strong City | do | 20 | 1.3 | 101 | 12 | 7.9 | 128 | 87 | 12 | ........ | ........ |
| 14 | Oct. 3, 1901 | Cottonwood River, at Emporia | do | ........ | ........ | 101 | 27 | 12 | 106 | 179 | 19 | 94 | 541 |
| 15 | Nov. 15, 1902 | Neosho River, at Neosho Rapids | do | 24 | 1.2 | 93 | 18 | 11 | 152 | 54 | 15 | ........ | ........ |
| 16 | Nov. 7, 1902 | Neosho River, at Burlington | do | 24 | 1 | 62 | 12 | 4.6 | 105 | 26 | 9.1 | ........ | ........ |
| 17 | ........ | Neosho River, at Leroy | Missouri Pacific Ry | 18 | 3.8 | 68 | 15 | 14 | 126 | 40 | 8.3 | 21 | 316 |
| 18 | Nov. 7, 1902 | Neosho River, at Neosho Falls | Kennicott Water Softener Co | 20 | 1 | 37 | 6.6 | 11 | 61 | 19 | 15 | ........ | ........ |
| 19 | do | Neosho River, at Iola | do | 18 | 1.9 | 63 | 11 | 3.9 | 98 | 28 | 12 | ........ | ........ |
| 20 | do | Neosho River, at Chanute | Atchison, Topeka & Santa Fe Ry. | 25 | 1.6 | 19 | 3 | 9 | 36 | 4 | 11 | ........ | ........ |
| 21 | Dec. 10, 1906 | Coal Creek, at Humboldt | Kennicott Water Softener Co | 14 | 2.2 | 79 | 13 | 3 | 111 | 53 | 12 | ........ | ........ |

[a] Obtained by computation to ionic form; results originally stated as in hypothetical combinations.

[b] $SiO_2+Fe_2O_3+Al_2O_3$.

## COTTONWOOD RIVER.[1]

### DESCRIPTION.

Cottonwood River rises northeast of Canton in the northeastern part of McPherson County and flows northeastward to a point a little beyond Moore, in the northwestern part of Marion County, where it turns and flows southeastward across Marion County; at Florence, it turns again and takes a general northeasterly course across Chase County into Lyon County, where at Wiggam it unites with Neosho River.

The principal tributaries of Cottonwood River are Doyle Creek and South Fork of Cottonwood River, both of which enter from the south. From the source of the river to its mouth, the distance in a straight line is about 75 miles, and the river falls from an elevation of about 1,475 feet to 1,045 feet above sea level. The drainage area has an extreme width of about 40 miles and comprises 1,880 square miles. The land is hilly or gently rolling prairie, pasture, or cultivated land,

The channel of the river is in Permian deposits across Marion County nearly to Clements in Chase County, where it enters the Pennsylvanian series, in which it continues to its confluence with the Neosho.

### QUALITY OF WATER.

The United States Geological Survey, with the help of Alva J. Smith, city engineer, maintained a daily sampling station on Cottonwood River at Emporia from December 4, 1906, to December 3, 1907. John M. Hilton was collector.

A record of the analyses of composites of the samples is presented in Table 180. The table shows that the water of the river is highly mineralized for a surface water, is high in calcium, magnesium, bicarbonates, and sulphates, and is low in chlorides. The temporary hardness is usually and the permanent hardness is always high.

Measurements of the turbidity of the Cottonwood made daily with a United States Geological Survey turbidity rod during ten months, from August, 1904, to July, 1905, are recorded in Table 181. During about 54 per cent of the time the turbidity was less than 50. A long period of low turbidity extended from August 26 to November 30, 1904. From February 1 to 22, 1905, the turbidity was less than 10. A period of high turbidity extended from May 10 to 19, 1905, and another from May 25 to June 9, 1905. The lowest turbidity, 7, was recorded many times in February, 1905, and the highest, 3,000, on several occasions during May, June, and July, 1905.

The turbidity of the daily samples that were collected at Emporia from December 4, 1906, to December 3, 1907, is recorded in Table 182. Of the 333 readings, a little over 50 per cent were less than 50 and a

[1] Water-Supply Paper U. S. Geol. Survey No. 147, 1905, p. 90.

trifle over 16 per cent were 100 or more. Periods of long-continued low turbidity were noted from December 4, 1906, to January 18, 1907, March 17 to June 22, 1907, July 3 to August 19, 1907, August 24 to October 1, 1907, and October 26 to December 3, 1907.

The longest period of high turbidity extended from June 23 to July 3, 1907. The lowest turbidity, 5, was recorded on January 11, 1907, and the highest, 2,340, on June 26, 1907. The coefficient of fineness, Table 180, most of the time was high, but nine times it fell below 0.65. The record thus indicates that the matter carried in suspension by the river is coarse usually, but that part of the time it was fine enough to make the use of a coagulant advantageous in filtration works.

Tests of the water of Cottonwood River above Emporia (assays 10 to 19, Table 178, and analyses 5 to 7, with analyses 9 to 11, Table 179), show waters very high in sulphates, presenting marked contrast to water of the Neosho River above Emporia. In explanation of the difference it may be said that Cottonwood River and its tributaries above Cedar Point flow within that part of the Permian area that is known to contain gypsum deposits. Thus in Marion County gypsum outcrops on French Creek, South Cottonwood River, and on Doyle Creek in Risely, Liberty, and East Branch townships.[1] It is said that there is a gypsum deposit on Doyle Creek in Harvey County,[2] and on Liberty Creek, 5 miles west of Peabody.[3] The statements probably refer to the same deposit. Doubtless there are outcrops of gypsum on other tributaries of Cottonwood River above Cedar Point, and it is possible that springs, such as that in Central Park at Marion (p. 133), that are high in sulphates by reason of having come in contact with gypsiferous rocks, contribute sulphates to Cottonwood River. The waters of which assays 10 to 19 are tests have very great permanent hardness and most of them marked temporary hardness as well.

The tributaries of the Cottonwood that through most of their courses flow in Pennsylvanian rocks (assays 20 to 23, Table 178), are low in sulphates and, with the exception of Buckeye Creek, carry a moderate amount of bicarbonates. They are therefore dissimilar to the tributaries of Cottonwood River above Cedar Point and are like those of the Neosho above Emporia. Tests of the water of Cottonwood River at different places between Clements and Emporia (assay 24, Table 178, and analyses 12 to 14, Table 179), show that it has high permanent and moderate temporary hardness.

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[1] First Bienn. Rept. State Board Agr., p. 292; Fourth Bienn. Rept., p. 237.
[2] Kansas, her story and statistics: Kansas State Board Agr., vol. 26, No. 101, p. 146.
[3] Kansas Univ. Geol. Survey, vol. 5, p. 67.

TABLE 180.—*Analyses of water from Cottonwood River at Emporia, Kans.*

[Drainage area 1,880 (estimated) square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Dec. 4 | Dec. 13 | 35 | 17 | 0.49 | 18 | 0.40 | 144 | 28 | 31 | 0.0 | 387 | 203 | 1.1 | 14 | 625 |
| Dec. 14 | Dec. 23 | 16 | 10 | .62 | 13 | .50 | 133 | 30 | 29 | .0 | 395 | 199 | 1.8 | 15 | 602 |
| | 1907. | | | | | | | | | | | | | | |
| Dec. 24 | Jan. 4 | 8 | 4 | .50 | 27 | .8 | 123 | 31 | 27 | .0 | 353 | 157 | 4.0 | 16 | 540 |
| 1907. | | | | | | | | | | | | | | | |
| Jan. 5 | Jan. 17 | 17 | 18 | 1.06 | 36 | 1.0 | 100 | 28 | 32 | .0 | 263 | 162 | 2.1 | 16 | 503 |
| Jan. 18 | Jan. 30 | 864 | 694 | .80 | 40 | 2.4 | 70 | 6.1 | 28 | a7.4 | 236 | 61 | 4.4 | 6.9 | 328 |
| Feb. 1 | Feb. 13 | 58 | 47 | .81 | 55 | .12 | 104 | 21 | 28 | 0 | 370 | 93 | 2.1 | 7.6 | 446 |
| Feb. 14 | Feb. 23 | 25 | 21 | .84 | 34 | .20 | 120 | 22 | 28 | 4.0 | 365 | 139 | 3.7 | 11 | 528 |
| Feb. 24 | Mar. 5 | 405 | 354 | .87 | 31 | .18 | 103 | 22 | 35 | .0 | 296 | 101 | 4.0 | 8.4 | 441 |
| Mar. 6 | Mar. 15 | 644 | 485 | .75 | 19 | .18 | 75 | 15 | 21 | .0 | 226 | 73 | 4.6 | 6.1 | 321 |
| Mar. 16 | Mar. 25 | 68 | 77 | 1.13 | 19 | 2.4 | 100 | 19 | 27 | .0 | 327 | 65 | 1.1 | 6.8 | 386 |
| Mar. 28 | Apr. 6 | 50 | 38 | .76 | 14 | 1.0 | 112 | 25 | 25 | .0 | 364 | 111 | 3.8 | 7.2 | 462 |
| Apr. 7 | Apr. 16 | 45 | 44 | .98 | 9.2 | 3.2 | 99 | 21 | 24 | .0 | 298 | 128 | 1.1 | 11 | 457 |
| Apr. 17 | Apr. 26 | 37 | 23 | .62 | 5.8 | .8 | 102 | 29 | 28 | .0 | 317 | 148 | 1.3 | 11 | 482 |
| Apr. 27 | May 6 | 92 | 147 | 1.60 | 12 | 1.8 | 98 | 15 | 28 | .0 | 315 | 133 | 1.3 | 10 | 446 |
| May 7 | May 17 | 117 | 89 | .76 | 13 | 1.4 | 93 | 5.5 | 22 | .0 | 302 | 100 | 3.8 | 9 | 384 |
| May 18 | May 28 | 34 | 46 | 1.35 | 19 | .8 | 93 | 11 | 28 | .0 | 365 | 123 | 3.0 | 11 | 433 |
| May 29 | June 7 | 69 | 51 | .74 | 14 | 1.0 | 100 | 27 | 27 | .0 | 355 | 120 | 1.9 | 10 | 444 |
| June 8 | June 18 | 54 | 48 | .89 | 12 | .6 | 112 | 28 | 28 | .0 | 345 | 133 | 10 | 12 | 285 |
| June 19 | June 28 | 930 | 755 | .81 | 21 | 1.5 | 85 | 21 | 26 | 0 | 252 | 95 | 5.5 | 8 | 368 |
| June 29 | July 8 | 120 | 103 | .86 | 25 | 3 | 90 | 25 | 29 | a9.5 | 278 | 93 | 6.5 | 9 | 391 |
| July 9 | July 20 | 63 | 50 | .79 | 24 | 1.0 | 109 | 27 | 29 | a7.0 | 320 | 111 | 4.5 | 9.5 | 421 |
| July 22 | July 31 | 43 | 33 | .77 | 24 | 1.0 | 102 | 31 | 29 | .0 | 337 | 122 | 2.5 | 11 | 448 |
| Aug. 1 | Aug. 11 | 30 | 26 | .87 | 23 | .8 | 119 | 30 | 37 | .0 | 322 | 160 | 3.0 | 11 | 506 |
| Aug. 12 | Aug. 21 | 87 | 63 | .72 | 23 | .50 | 91 | 27 | 29 | .0 | 310 | 122 | 2.0 | 10 | 411 |
| Aug. 22 | Sept. 2 | 100 | 55 | .55 | 14 | .16 | 87 | 23 | 23 | .0 | 250 | 98 | 3.0 | 9.0 | 364 |
| Sept. 3 | Sept. 14 | 39 | 28 | .72 | 18 | .12 | 108 | 36 | 35 | .0 | 318 | 178 | 2.4 | 10 | 508 |
| Sept. 16 | Sept. 27 | 43 | 45 | 1.04 | 17 | 1.4 | 96 | 36 | 33 | .0 | 285 | 189 | 1.1 | 13 | [illegible] |
| Sept. 28 | Oct. 8 | 64 | 170 | 2.66 | 20 | .28 | 110 | 32 | 29 | .0 | 260 | 190 | 2.7 | 11 | 504 |
| Oct. 9 | Oct. 18 | 86 | 53 | 62 | 18 | .35 | 81 | 22 | 29 | .0 | 222 | 95 | 3.2 | 15 | 352 |
| Oct. 19 | Oct. 28 | 66 | 22 | .33 | 19 | .13 | 94 | 26 | 26 | .0 | 250 | 126 | 2.0 | 10 | 416 |
| Oct. 30 | Nov. 8 | 70 | 28 | .40 | 20 | .16 | 91 | 24 | 24 | .0 | 256 | 106 | 2.3 | 12 | 389 |
| Nov. 9 | Nov. 20 | 41 | ....... | ...... | 19 | .26 | 118 | 34 | 28 | .0 | 350 | 222 | 1.1 | 14 | 563 |
| Nov. 21 | Dec. 3 | 32 | 4.0 | .12 | 20 | .12 | 100 | 30 | 33 | .0 | 360 | 167 | 1.0 | 13 | 452 |
| Mean........ | | 135 | 114 | .84 | 21 | .90 | 102 | 24 | 28 | .0 | 312 | 131 | 3.0 | 11 | 445 |
| Per cent of anhydrous residue.... | | ..... | ....... | ...... | 4.4 | .3 | 21.5 | 5.0 | 5.9 | 32.4 | ..... | 27.6 | .6 | 2.3 | .... |

a Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 4, 1906, to January 30, 1907, and from March 16 to November 20, 1907, by F. W. Bushong; from February 1 to March 15, 1907, and from November 21 to December 3, 1907, by Archie J. Weith.

TABLE 181.—*Daily turbidity measurements of Cottonwood River at Emporia, Kans.*

[Alva J. Smith and J. B. Soden, observers.]

| Day. | Turbidity, 1904. | | | | Turbidity, 1905. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Aug. | Sept. | Oct. | Nov. | Feb. | Mar. | Apr. | May. | June. | July. |
| 1 | 85 | 35 | 35 | 13 | 7 | 130 | 500 | 35 | 500 | 60 |
| 2 | 90 | 35 | 45 | 12 | 7 | 100 | 250 | 45 | 250 | 3,000 |
| 3 | 90 | 30 | 45 | 12 | 7 | 80 | 250 | 40 | 3,000 | 3,000 |
| 4 | 55 | 30 | 35 | 12 | 7 | 75 | 150 | 40 | 3,000 | 3,000 |
| 5 | 50 | 30 | 35 | 12 | 9 | 60 | 100 | 40 | 1,500 | 3,000 |
| 6 | 45 | 24 | 35 | 14 | 7 | 60 | 100 | 50 | 600 | 400 |
| 7 | 45 | 30 | 40 | 14 | 7 | 60 | 95 | 60 | 350 | 200 |
| 8 | 45 | 30 | 40 | 12 | 7 | 55 | 95 | 70 | 130 | 130 |
| 9 | 40 | 28 | 35 | 12 | 7 | 55 | 90 | 70 | 110 | 130 |
| 10 | 40 | 30 | 35 | 12 | 7 | 50 | 85 | 1,500 | 95 | 3,000 |
| 11 | 35 | 30 | 35 | 12 | 7 | 40 | 85 | 1,500 | 80 | 300 |
| 12 | 35 | 35 | 35 | 14 | 7 | 30 | 65 | 800 | 70 | 150 |
| 13 | 30 | 26 | 40 | 14 | 7 | 30 | 55 | 800 | 65 | 75 |
| 14 | 24 | 30 | 50 | 15 | 7 | 30 | 55 | 600 | 60 | 70 |
| 15 | 24 | 35 | 60 | 16 | 7 | 30 | 55 | 400 | 60 | 65 |
| 16 | 28 | 30 | 60 | 14 | 7 | 40 | 50 | 150 | 65 | 60 |
| 17 | 26 | 30 | 50 | 14 | 7 | 40 | 50 | 140 | 350 | 55 |
| 18 | 30 | 30 | 40 | 14 | 7 | 120 | 50 | 120 | 3,000 | 50 |
| 19 | 30 | 30 | 35 | 14 | 7 | 200 | 50 | 110 | 3,000 | 45 |
| 20 | 40 | 30 | 40 | 14 | 7 | 200 | 50 | 95 | 300 | 40 |
| 21 | 40 | 26 | 35 | 14 | 7 | 180 | 50 | 75 | 80 | 35 |
| 22 | 40 | 30 | 25 | 14 | 8 | 150 | 50 | 65 | 300 | 35 |
| 23 | 300 | 45 | 25 | 14 | 80 | 180 | 50 | 65 | 200 | 40 |
| 24 | 400 | 35 | 16 | 14 | 150 | 180 | 50 | 60 | 180 | 40 |
| 25 | 160 | 28 | 16 | 14 | ........ | 180 | 60 | 300 | 140 | 40 |
| 26 | 80 | 28 | 14 | 14 | 200 | 180 | 75 | 300 | 120 | 35 |
| 27 | 45 | 35 | 14 | 12 | 250 | 180 | 60 | 300 | 100 | 35 |
| 28 | 30 | 45 | 12 | 12 | 160 | 2,000 | 50 | 3,000 | 90 | 35 |
| 29 | 30 | 35 | 12 | 12 | ........ | ........ | 40 | 3,000 | 80 | 50 |
| 30 | 30 | 40 | 14 | 12 | ........ | ........ | 40 | 600 | 60 | 50 |
| 31 | 45 | ........ | 14 | ........ | ........ | ........ | ........ | 500 | ........ | 55 |
| Mean | 67 | 32 | 33 | 13 | 37 | 168 | 94 | 482 | 598 | 557 |

TABLE 182.—*Turbidity of daily samples from Cottonwood River at Emporia, Kans.*

[Readings made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1 | ...... | 7 | 30 | 2,400 | 40 | 36 | 75 | 200 | 45 | 60 | 45 | 100 | 30 |
| 2 | ...... | 7 | ...... | 400 | 48 | 36 | 65 | 190 | 34 | 65 | 520 | 70 | 16 |
| 3 | ...... | 13 | ...... | 400 | 72 | 35 | 65 | 110 | 27 | 36 | 440 | 50 | 18 |
| 4 | 24 | 7 | 20 | 392 | 42 | 50 | 65 | 90 | 45 | 36 | 933 | 80 | ...... |
| 5 | 24 | 9 | 20 | 160 | 45 | 613 | 82 | 65 | 36 | 32 | 180 | 40 | ...... |
| 6 | 32 | ...... | 27 | 140 | 47 | 600 | 65 | 80 | 22 | 40 | 200 | 60 | ...... |
| 7 | 35 | 20 | 28 | 85 | 48 | 613 | 65 | 75 | 27 | ...... | 95 | 60 | ...... |
| 8 | 28 | 14 | 45 | 42 | 48 | 65 | 65 | 55 | 22 | 36 | 100 | 50 | ...... |
| 9 | 24 | 16 | 338 | 460 | 46 | 65 | 73 | 50 | 24 | 40 | 60 | 80 | ...... |
| 10 | 14 | 20 | ...... | 1,226 | 46 | ...... | ...... | 55 | 24 | 45 | 60 | 70 | ...... |
| 11 | 12 | 5 | 160 | 1,400 | 50 | 75 | 55 | 80 | 24 | 50 | 120 | 50 | ...... |
| 12 | 20 | 19 | 160 | 1,000 | 55 | 58 | 55 | 65 | 22 | 45 | 90 | 45 | ...... |
| 13 | 30 | ...... | 50 | 1,264 | 45 | 65 | 55 | 45 | 30 | 40 | 90 | 60 | ...... |
| 14 | 24 | 24 | 65 | 510 | 40 | 60 | 46 | ...... | 48 | 32 | 90 | 36 | ...... |
| 15 | 24 | 20 | 24 | 295 | 40 | 60 | 60 | 65 | 32 | ...... | 75 | 24 | ...... |
| 16 | 18 | ...... | 27 | 100 | 55 | 55 | 36 | 85 | 28 | 50 | 100 | 16 | ...... |
| 17 | 18 | 19 | 15 | 60 | 32 | 55 | 34 | ...... | 45 | 40 | 90 | 24 | ...... |
| 18 | 15 | 12 | 22 | 85 | 38 | ...... | 60 | 65 | 40 | 36 | 50 | 18 | ...... |
| 19 | 12 | 3,320 | 24 | 95 | 32 | ...... | 55 | 65 | 42 | 36 | 50 | 32 | ...... |
| 20 | 15 | ...... | 17 | 68 | 24 | 65 | 43 | 50 | 65 | 70 | 60 | 40 | ...... |
| 21 | 8 | 1,230 | 22 | 55 | 37 | ...... | 60 | ...... | 520 | 32 | 70 | 45 | ...... |
| 22 | 10 | 2,000 | 20 | 75 | 50 | ...... | 58 | 44 | 210 | 30 | 60 | 50 | ...... |
| 23 | 12 | 1,150 | 16 | 45 | 25 | 65 | 2,200 | 32 | 262 | 30 | 40 | 36 | ...... |
| 24 | 10 | 532 | 16 | 47 | 46 | 75 | 2,200 | 50 | 145 | 45 | 50 | 30 | ...... |
| 25 | ...... | 180 | 12 | 47 | 60 | ...... | 1,732 | 45 | 70 | ...... | 90 | 45 | ...... |
| 26 | 11 | 105 | 26 | ...... | 35 | ...... | 2,340 | 50 | 55 | 50 | 100 | 45 | ...... |
| 27 | 7 | ...... | 26 | ...... | 35 | ...... | 425 | 36 | 85 | 50 | 80 | 30 | ...... |
| 28 | 7 | 70 | 200 | 60 | 35 | ...... | 180 | 38 | 80 | 50 | 45 | 24 | ...... |
| 29 | 6 | ...... | ...... | 48 | 45 | 65 | 160 | 42 | 30 | 70 | ...... | 18 | ...... |
| 30 | ...... | 42 | ...... | 47 | 34 | 65 | 180 | 46 | 31 | 65 | 100 | 30 | ...... |
| 31 | 7 | ...... | ...... | 55 | ...... | 80 | ...... | 50 | ...... | ...... | 90 | ...... | ...... |
| Mean | 17 | 368 | 56 | 381 | 43 | 134 | 367 | 69 | 72 | 45 | 140 | 45 | 21 |

NOTE.—Average May 18 to 28, 34. Turbidities above 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the readings were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

## SPRING RIVER.

### DESCRIPTION.

Spring River rises in the southern part of Lawrence County, Mo., and takes a general northwesterly course to the northwest corner of Jasper County, where, at Galesburg, it receives North Fork of Spring River, and turns sharply to the southwest, passes across the southeastern corner of Kansas into Oklahoma, and joins the Neosho [1] northwest of Wyandotte in Ottawa County. It is believed that so much of North Fork of Spring River as is above Marshall was at one time part of Dogwood Creek and so discharged into the Osage, but was captured by that part of North Fork below Marshall, which once was an independent stream, and by working north rapidly in the soft shale cut off the stream above Marshall from the Osage. Besides North Fork, the three principal tributaries of Spring River in Missouri are, in order from north to south, Center, Turkey, and Shoal Creeks. These streams flow down the northwestern slope of the Ozark dome and with the main stream itself and some minor tributaries drain the entire Joplin mining district.[2] The three streams are perennial, carry water in abundance, and have a general northwesterly course. Their tributaries enter at nearly right angles, are very short—only a few being over 4 or 5 miles in length—and many of them are dry except after a rain, though some, being spring fed, have a constant flow, and some receive a constant volume of water that is pumped from the mines.

The average fall of Spring River in the Galena-Joplin district is 3.6 feet to the mile, though locally it is considerably greater. The average fall of Center Creek is 6.3 feet and of Shoal Creek, 7 feet to the mile. The direction of the major drainage lines, except that part of Spring River which flows southwestward, has probably been determined by the configuration of the general slope of the Ozark Uplift, though Shoal Creek occupies a structural depression that may have determined its position. The general southwesterly course of that part of Spring River lying in Kansas has doubtless been inherited from earlier conditions in which it was determined by the original slope of the Ozark dome, but its immediate position appears to have been fixed by the line of contact between the Cherokee shale and Boone formation. When a soft formation overlies a harder one, both dipping at a moderate angle, the general tendency of a stream flowing parallel to the strike of the rocks, unless checked in some way, is to follow constantly the contact between the two formations, working down the slope as the edge of the softer rocks is gradually eroded.

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[1] Missouri Geol. Survey, vol. 10, pp. 83–84.

[2] The following description is abstracted from Joplin folio (No. 148), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 2.

This, as pointed out by Adams,[1] appears to have been the case with Spring River. It has followed the edge of the Cherokee shale to its present position, where comparatively recent and more active cutting has caused it to become intrenched in the harder Boone formation close to the line of contact.

The dissection of the district is moderate. Important streams are not numerous, and those present are separated by broad, flat-topped divides. In the area underlain by the Boone formation these divides are cut by many small, shallow, and open valleys formed by the headwaters of tributary streams. In their lower courses these tributary valleys are deeper and less open, and they are here and there bordered by low cliffs of limestone and chert. Such tributary valleys lie along all the more important stream courses of the district. They are deep adjacent to the deeper main valleys and are an especially pronounced feature along Shoal Creek, where near their mouths they range in depth from 80 to about 150 feet. In the Cherokee shale the dissection is much less than in the Boone and the valleys are on the whole much shallower, more open, and less numerous. Even the larger valleys in this formation, as those of Shawnee and Cow creeks, are open and very shallow.

The largest stream valleys of the district are comparatively broad and flat, and here and there, as along Shoal Creek and the lower reaches of Spring River, are rudely terraced. While the valley bottoms are generally covered with alluvium, those of Shoal Creek and some of the tributaries are locally floored with bare rock. At Baxter Springs, just before leaving the district, Spring River enters a narrower, deeper valley, which seems younger than the valley above that point.

The valley slopes consisting of the Cherokee shale are very gentle, but those formed by the Boone formation are more abrupt. Cliffs are common in the Boone valleys, especially where the walls are being undercut by the stream meanders. Since the upland surface rises toward the south, while the general drainage of the district is to the southwest, the larger valleys are deeper in their southern parts. The valley of Shoal Creek is the deepest in the district. West of Grand Falls the bluff hills bordering this stream reach a maximum height of about 150 feet.

The terraces of the district are of two varieties, the alluvial flats and the rock shelves; the former are confined to the river valley and the latter are found mainly along Shoal Creek. The best example of the alluvial terrace is on the east side of Spring River, extending southward from the village of Lowell for 3 miles. It has an elevation of about 15 feet above the stream and a width of half a mile.

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[1] Trans. Kansas Acad. Sci., vol. 16, 1899, p. 56.

The terrace front descends abruptly to the river bottom, while the surface rises very gently to the bordering hills. At the south end it loses its terrace character and becomes an alluvial slope similar to those on the south side of Shoal Creek. Another terrace lies on the same side of Spring River just northeast of Lowell. A third well-developed terrace, about 160 acres in extent, lies east of Spring River and south of Short Creek.

In many places on each side of Spring River, from Baxter Springs to Waco, the upland plain slopes so gently toward the river that it is quite impossible to distinguish the limits of the present flood plain except by noting the height of the high water in the flooded stream. This is true in the vicinity of Varck, and likewise west and north of Smithfield. On the flat west and southwest of the old Boston Mills the terrace, or second bottom, lies at an elevation of 10 feet or so above the alluvial flood plain, and is limited on the north by another flat, or third bottom, 15 to 30 feet above it, corresponding to the lower country about and east of Eldon.

No second bottom is distinguishable in the great bend south of Messer post office nor in the bend west and north of Smithfield, but the alluvial plain passes gradually into the upland. These conditions continue upstream to a point east of Waco, where a well-developed terrace is exhibited on each side of the river. The absence of the terraces in this interval is due to the fact that they have been removed by erosion that has lowered the river to its present level.

Along Shoal Creek in a number of places the creek bottom is bordered by a terrace 20 to 40 feet or more in height, the front of which is a sheer wall of massive chert. These rock-shelf terraces are not true stream terraces, as they do not represent graded sections of the stream valley which have been abandoned by the deeper cutting of the stream; moreover, they do not lie at any uniform elevation above the present grade of Shoal Creek. On the contrary, they are but gentle swells in the more resistant Grand Falls chert member of the Boone formation which have been etched into relief and cut through by the stream in the process of lowering its bed. At Grand Falls, the type locality, Shoal Creek is even now attacking one of the more resistant of these bosses of chert. Good examples of these rock shelves are found about Grand Falls and along the stream as far as Gregg's bridge, 2 miles below; also from Reding's Mill to a point below the mouth of Silver Creek.

On the south side of Shoal Creek, about 2 miles southeast of Lowell, the land slopes gently from the creek bank to the foot of the hill a quarter of a mile south, rising 35 to 40 feet in that distance. Just at this point a valley about 300 yards long debouches from the south, forming a well-marked, little alluvial fan. This suggests that the slopes are aggradation plains built up of outwash from the hills by the coalescing of alluvial fans, and are thus alluvial slopes. This suggestion is borne out by the fact, shown by well sections, that the slope down to the level of the stream is made up of gravel and wash materials.

A characteristic slope of this kind lies on the south side of Shoal Creek due south of Galena, and others occur on each side of the creek. By far the largest and best developed commences at Gregg's bridge, 2 miles west of Grand Falls, and stretches westward along the south side of Shoal Creek valley, a distance of 2 miles to a point within a mile of the State line. This alluvial slope is over half a mile in width. The edge adjacent to the hills is 55 to 60 feet higher than the banks of the creek. A little west of the middle of the slope a valley, perhaps a quarter of a mile in length, at the foot of which is a very plain alluvial fan, comes down from the southern hills.

Various wells at the southern margin of this slope penetrate from 30 to 40 feet into it, the material without exception being rock fragments, gravel, sand, and clay—typical wash material. This shows that the valley throughout its width has been eroded to about the level of the present stream and has been refilled in part by inwash from the sides. Only the shorter side valleys exhibit alluvial fans, the reason being that the larger tributaries, having cut nearer to grade, experience no great change in slope on reaching the main valley, and, therefore, drop no great amount of material at that point.[1]

From the west in Kansas[2] the principal tributaries received by Spring River in order, from north to south, are Cow, Shawnee, Brush, and Willow creeks, all but the last of which drain the coal-mining regions of the southeastern part of Crawford County and the eastern part of Cherokee County, and so are contaminated by the acid mine waters and by sewage from the larger cities. On the west side of Spring River in Kansas the drainage is to the southeast. In general, the streams make an angle of about 150° with those on the east side of the river. Throughout the area the surface slopes to the east and southeast, or down into the trough of Spring River. These streams that enter Spring River from the east rise on the uplands of Cherokee and Crawford counties, where the elevation is not over 900 feet, so that they are not unlike those that drain the mining region proper. Their fall is not quite so great, and as they flow on the soft beds of the Cherokee shale their valleys are usually wider, and their bluffs are neither so high nor so precipitous. Spring River itself has a crooked course in Kansas, which is accounted for by its having eroded its channel through the soft shales of the "Coal Measures" down to the hard Mississippian rocks. So the flood plain of the river rests on the upper surface of the Mississippian, which

[1] End of description taken from Joplin folio (No. 148), Geol. Atlas U. S.
[2] Kansas Univ. Geol. Survey, vol. 8, pp. 46–49.

is exposed in the bottom of the river at Lowell and other places. Now, in every place where the river makes a bold curve to the west it has glided westward on top of the Mississippian by cutting into the "Coal Measure" shales. The tendency of the river to shift its channel to the west is accentuated at those places where creeks from the east enter the main stream. Seemingly the increased current due to these creeks has inclined the river to cut into the soft shales of the "Coal Measures" on its eastern banks in preference to eroding the hard Mississippian rocks. Furthermore, some of the creeks from the west enter the river nearly opposite the creeks from the east, which by eroding the eastern bank have apparently coaxed the river from its straight course at the same time that the eastern creeks were pushing it westward.

Judged by one year's turbidity readings, Spring River is subject to sudden floods of brief duration. The river has the reputation of being treacherous, and the principal tributaries are said to subside slowly after they reach high stages.

The area of the drainage basin of Spring River at Baxter Springs is 1,890 square miles.

### QUALITY OF WATER.

The United States Geological Survey maintained a daily sampling station on Spring River at Baxter Springs from December 1, 1906, to November 30, 1907. Paul E. Mason was collector.

The results of the analyses of the composites of the samples are recorded in Table 183. The table shows that the water is not highly mineralized. It should usually be classed as a calcic alkaline water of low temporary and high permanent hardness. All the samples of December 1 to 10, January 11 to 20, April 27 to May 6, May 27 to June 6, June 19 to 30, October 22 to 23, November 1 to 10, November 11 to 20, and November 21 to 30 were calcic saline in character.

A record of the turbidity of the daily samples collected at Baxter Springs appears in Table 184. The series of readings shows Spring River to be one of the clearest rivers in the State. Over 78 per cent of the 344 readings were less than 50 and less than 1 per cent reached 100 or more. The lowest turbidity, 3, was recorded on January 3, 1907, and the highest 933, on May 14, 1907. The coefficient of fineness, Table 183, is usually high, but twice it falls below 0.65; the matter carried in suspension by the river is, therefore, normally coarse.

TABLE 183.—*Analyses of water from Spring River at Baxter Springs, Kans.*

[Drainage area, 1,890 square miles. Quantities in parts per million. Analyses made in the chemical laboratories of the University of Kansas, E. H. S. Bailey, director.]

| Date. From— | Date. To— | Turbidity. | Suspended matter. | Coefficient of fineness. | Silica ($SiO_2$). | Iron (Fe). | Calcium (Ca). | Magnesium (Mg). | Sodium and potassium (Na+K). | Carbonate ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Nitrate ($NO_3$). | Chlorine (Cl). | Total dissolved solids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906. | 1906. | | | | | | | | | | | | | | |
| Dec. 1 | Dec. 10 | 20 | 15 | 0.75 | 6.4 | 0.40 | 81 | 5.3 | 32 | 0.0 | 157 | 130 | 3.5 | 11 | 319 |
| Dec. 11 | Dec. 20 | 11 | 11 | 1.00 | 8.0 | .50 | 69 | 5.7 | 24 | *a* 2.4 | 171 | 80 | 2.9 | 7.6 | 268 |
| Dec. 21 | Dec. 31 | 10 | 11 | 1.10 | 8.0 | .6 | 64 | 12 | 20 | .0 | 170 | 88 | 3.9 | 7.2 | 282 |
| 1907. | 1907. | | | | | | | | | | | | | | |
| Jan. 1 | Jan. 10 | 15 | 19 | 1.27 | 18 | 1.2 | 77 | 16 | 20 | .0 | 149 | 132 | 4.6 | 12 | 330 |
| Jan. 11 | Jan. 20 | 187 | 217 | 1.16 | 13 | 2.0 | 48 | 4.8 | 32 | .0 | 103 | 88 | 6.0 | 8.0 | 234 |
| Jan. 21 | Jan. 30 | 72 | 76 | 1.06 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Jan. 31 | Feb. 9 | 16 | 24 | 1.50 | 10 | 1.0 | 57 | 1.5 | 15 | .0 | 130 | 54 | 10 | 4.9 | 200 |
| Feb. 10 | Feb. 19 | 9 | 20 | 2.22 | 29 | .10 | 66 | 8.1 | 19 | .0 | 188 | 60 | 4.9 | 6.9 | 276 |
| Feb. 20 | Mar. 3 | 11 | 16 | 1.45 | 51 | .24 | 65 | 5.2 | 29 | .0 | 147 | 74 | 4.8 | 4.2 | 301 |
| Mar. 4 | Mar. 13 | 26 | 30 | 1.15 | 65 | .30 | 63 | 3.5 | 30 | .0 | 147 | 74 | 4.0 | 6.6 | 325 |
| Mar. 14 | Mar. 24 | 31 | 39 | 1.26 | 7 | .8 | 55 | 9.7 | 22 | .0 | 149 | 61 | 4.8 | 6.2 | 235 |
| Mar. 25 | Apr. 4 | 43 | 39 | .91 | 7 | .8 | 65 | 1.6 | 25 | .0 | 154 | 77 | 4.6 | 5.8 | 260 |
| Apr. 5 | Apr. 15 | 19 | 17 | .89 | 3.2 | 3.0 | 68 | 2.1 | 18 | .0 | 157 | 72 | 4.5 | 7.5 | 250 |
| Apr. 16 | Apr. 26 | 18 | 8 | .44 | 0.0 | 1.5 | 63 | 3.2 | 18 | .0 | 156 | 72 | 5.0 | 6.5 | 246 |
| Apr. 27 | May 6 | 130 | 127 | .98 | 7.6 | 4.0 | 56 | 9.8 | 21 | .0 | 97 | 89 | 6.0 | 7.0 | 229 |
| May 7 | May 16 | 274 | 293 | 1.07 | 17 | 7.5 | 38 | 4.6 | 17 | .0 | 80 | 43 | 7.5 | 7.0 | 164 |
| May 17 | May 26 | 88 | 134 | 1.52 | 29 | 1.6 | 49 | 2.0 | 18 | .0 | 112 | 45 | 8.0 | 8.0 | 182 |
| May 27 | June 6 | 27 | 24 | .89 | 6.2 | .9 | 64 | 9.5 | 19 | .0 | 142 | 70 | 7.5 | 8.0 | 241 |
| June 7 | June 18 | 63 | 63 | 1.00 | 5.6 | .6 | 66 | 6.6 | 21 | .0 | 133 | 86 | 7.2 | 9.0 | 251 |
| June 19 | June 30 | 178 | 173 | .97 | 12 | 1.5 | 52 | 7.7 | 20 | .0 | 98 | 80 | 7 | 5.5 | 210 |
| July 1 | July 10 | 110 | 109 | .99 | 16 | 1.5 | 50 | 15 | 17 | .0 | 110 | 54 | 6 | 6.0 | 181 |
| July 11 | July 20 | 66 | 73 | 1.10 | 16 | 1.0 | 66 | 7.1 | 25 | .0 | 138 | 61 | 6.5 | 6.0 | 215 |
| July 21 | Aug. 1 | 59 | 75 | 1.27 | 15 | 1.0 | 63 | 9.3 | 22 | .0 | 145 | 62 | 6.0 | 6.5 | 196 |
| Aug. 2 | Aug. 11 | 23 | 32 | 1.39 | 6.8 | 1.0 | 74 | 12 | 18 | .0 | 163 | 69 | 5 | 5 | 240 |
| Aug. 12 | Aug. 22 | 24 | 21 | .88 | 6.4 | 2.0 | 87 | 14 | 31 | .0 | 165 | 77 | 4.5 | 5.5 | 256 |
| Aug. 23 | Sept. 3 | 36 | 32 | .89 | 9.0 | .05 | 64 | 9.6 | 19 | .0 | 140 | 71 | 4.5 | 6.0 | 232 |
| Sept. 4 | Sept. 15 | 26 | 17 | .65 | 6.6 | .05 | 72 | 7.9 | 18 | .0 | 142 | 71 | 6.0 | 6.0 | 241 |
| Sept. 16 | Sept. 25 | 27 | 7 | .26 | 9.4 | .02 | 85 | 7.5 | 22 | .0 | 160 | 83 | 5.0 | 6.3 | 269 |
| Sept. 26 | Oct. 9 | 32 | 27 | .84 | 9.4 | .08 | 63 | 11 | 21 | .0 | 125 | 92 | 4.0 | 6.8 | 249 |
| Oct. 10 | Oct. 21 | 28 | 24 | .86 | 6.0 | .06 | 69 | 8.4 | 20 | .0 | 132 | 90 | 5.0 | 6.5 | 250 |
| Oct. 22 | Oct. 31 | 15 | 16 | 1.07 | 12 | .18 | 92 | 11 | 29 | .0 | 140 | 116 | 5.0 | 7.0 | 303 |
| Nov. 1 | Nov. 10 | 21 | 16 | .76 | 4.0 | .10 | 70 | 12 | 21 | .0 | 117 | 150 | 5.0 | 8.5 | 317 |
| Nov. 11 | Nov. 20 | 17 | 12 | .70 | 8.4 | .10 | 77 | 16 | 43 | .0 | 145 | 160 | 3.2 | 20 | 377 |
| Nov. 21 | Nov. 30 | 19 | 23 | 1.21 | 11 | .14 | 68 | 11 | 22 | .0 | 133 | 133 | 4.0 | 7.5 | 302 |
| Mean | | 52 | 54 | 1.04 | 13 | 1.1 | 66 | 8.2 | 23 | .0 | 139 | 84 | 5.3 | 7.3 | 255 |
| Per cent of anhydrous residue | | ..... | ..... | ..... | 4.7 | .6 | 24.0 | 2.9 | 8.3 | 24.6 | ..... | 30.4 | 1.9 | 2.6 | ..... |

*a* Abnormal; computed as $HCO_3$ in the average.

NOTE.—Analyses from December 1, 1906, to February 9, 1907, and from March 14 to November 30, 1907, by F. W. Bushong; from February 10 to March 13, 1907, by Archie J. Weith.

TABLE 184.—*Turbidity of daily samples from Spring River at Baxter Springs, Kans.*

[Readings made in the chemical laboratories of the University of Kansas. E. H. S. Bailey, director.]

| Day. | Dec., 1906. | 1907. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. |
| 1 | 48 | 3 | 8 | 18 | 35 | 270 | 24 | 412 | 60 | ...... | 15 | 5 |
| 2 | 8 | 34 | 12 | 12 | 20 | 190 | 17 | 180 | 34 | 24 | ...... | 8 |
| 3 | 10 | 6 | 27 | 3 | 34 | 120 | 22 | 120 | 25 | 45 | 30 | 16 |
| 4 | 12 | 5 | 18 | 25 | 32 | 60 | 26 | 100 | 24 | 32 | 15 | 18 |
| 5 | 12 | 7 | 7 | 22 | 20 | 150 | 30 | 80 | 25 | 45 | 16 | 18 |
| 6 | 10 | 15 | 7 | 32 | ...... | 275 | 27 | 65 | 8 | 16 | 70 | 30 |
| 7 | 5 | 24 | 2 | 30 | 27 | 315 | 26 | 38 | 43 | 36 | ...... | 18 |
| 8 | 8 | 30 | 10 | 18 | 13 | 150 | 16 | 38 | 27 | 15 | 70 | 32 |
| 9 | 9 | 17 | 50 | 42 | 18 | 70 | 325 | 40 | 24 | 12 | 50 | 50 |
| 10 | 16 | 22 | 12 | 32 | 27 | 60 | 53 | 30 | 22 | ...... | 45 | 12 |
| 11 | 5 | 24 | 6 | 17 | 13 | 55 | 53 | 28 | 18 | 32 | 50 | 10 |
| 12 | 15 | 22 | 5 | 27 | 18 | 55 | ...... | 45 | 22 | 50 | 24 | 12 |
| 13 | 18 | 32 | 4 | 15 | 15 | 58 | 50 | 45 | 20 | 16 | 36 | 10 |
| 14 | 10 | 40 | 20 | 14 | 20 | 933 | ...... | 85 | 15 | 12 | ...... | 12 |
| 15 | 12 | 60 | 4 | 32 | 15 | 600 | 16 | 34 | 14 | 15 | 18 | 16 |
| 16 | 8 | 198 | 15 | 26 | 14 | 440 | 18 | 45 | 36 | 18 | 12 | 16 |
| 17 | 20 | 160 | 6 | 45 | 20 | 312 | 18 | 110 | 55 | 10 | 30 | 18 |
| 18 | 10 | 160 | 6 | 40 | 13 | 65 | 53 | 100 | ...... | 36 | ...... | 24 |
| 19 | 10 | 512 | 8 | 32 | 19 | 58 | 55 | 70 | 22 | 10 | 16 | 18 |
| 20 | 5 | 665 | 5 | 33 | ...... | 65 | 22 | 95 | 14 | 20 | 16 | 36 |
| 21 | 12 | 325 | 7 | 40 | 14 | 60 | 16 | 75 | 22 | 30 | 32 | 18 |
| 22 | 33 | 140 | ...... | 33 | 18 | 85 | 85 | 53 | 22 | 80 | 24 | 15 |
| 23 | 15 | 80 | 10 | ...... | 13 | 105 | ...... | 190 | 16 | 12 | 24 | 12 |
| 24 | 10 | 40 | ...... | 10 | 30 | 60 | 22 | 44 | 57 | 24 | 15 | 12 |
| 25 | 7 | 45 | 16 | 18 | 21 | 45 | 370 | 22 | 34 | 30 | 16 | 16 |
| 26 | 5 | 27 | 9 | ...... | 20 | 33 | 440 | 30 | 34 | 18 | 24 | 18 |
| 27 | 5 | 12 | 16 | 24 | 24 | 34 | 440 | 40 | 30 | 30 | 10 | 18 |
| 28 | 7 | 20 | 12 | 165 | 30 | ...... | ...... | ...... | 40 | 24 | 8 | 45 |
| 29 | ...... | 14 | ...... | 40 | 30 | 22 | 130 | ...... | 65 | 24 | 12 | 16 |
| 30 | 7 | 15 | ...... | 35 | 150 | 45 | 200 | 26 | 15 | 18 | 12 | 18 |
| 31 | 4 | 15 | ...... | 27 | ...... | 18 | ...... | 50 | 32 | ...... | 10 | ...... |
| Mean | 12 | 89 | 12 | 31 | 26 | 160 | 98 | 79 | 29 | 26 | 26 | 19 |

NOTE.—Turbidities over 50 were determined with a Jackson turbidimeter and turbidities of 50 or less were determined by comparison with silica standards. Most of the turbidity determinations were made by Carrie M. Burlingame and Harvey G. Elledge; a few were made by Helen Heald and Adelbert Morrison.

TABLE 185.—*Assays of water of Spring River and its tributaries in Kansas.*

[Parts per million.]

| No. | Date. | Stream and locality. | Iron (Fe). | Carbonate radicle ($CO_3$). | Bicarbonate ($HCO_3$). | Sulphate ($SO_4$). | Chlorine (Cl). | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | 1905. | | | | | | | |
| 1 | July 3 | Cow Creek, above Girard sewer. | 1.5 | 0.0 | 88 | 35 | 6 | In high stage. |
| 2 | ...do..... | Cow Creek, 1 mile below sewer, 1 mile east of Girard. | .5 | .0 | 108 | 164 | 23 | Do. |
| 3 | July 5 | Cow Creek, 2 miles west and 1 mile south of Pittsburg. | Trace. | .0 | 114 | 61 | 14 | |
| 4 | July 6 | Middle Cow Creek, 1½ miles west and 1½ miles south of Pittsburg. | Trace. | .0 | 16 | 140 | 10 | Above dam of Hull & Dillon Packing Co. |
| 5 | ...do..... | Middle Cow Creek at Pittsburg. | .5 | .0 | 13 | 130 | 19 | 100 yards below dam of Hull & Dillon Packing Co. |
| 6 | July 5 | Cow Creek, below sewers 2 miles south of Pittsburg. | .5 | .0 | 72 | 113 | 13 | |
| 7 | ...do..... | Little Cow Creek, 2¾ miles east of Pittsburg. | 16.0 | .0 | Acid. | 431 | 36 | Contaminated by mine drainage. |
| 8 | July 10 | Reservoir at St. Louis & San Francisco Ry. pumping station south of Cherokee. | 1.0 | .0 | 44 | 124 | 10 | By Edward Bartow. |
| 9 | July 13 | Spring River, above Turkey Creek at Empire. | .0 | .0 | 119 | 37 | 7 | Do. |
| 10 | ...do..... | Turkey Creek, near its mouth at Empire. | .0 | .0 | 130 | 383 | 12 | Do. |

TABLE 185.—*Assay of water of Spring River and its tributaries in Kansas*—Continued.

| No. | Late. | Stream and locality. | Iron (Fe). | Carbonate radicle ($CO_3$). | Bicarbonate ($HCO_3$) | Sulphate ($SO_4$). | Chlorine (Cl). | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 11 | 1905. July 13 | Spring River, at bridge 1 mile north and 1 mile west of Empire. | 0.5 | 0.0 | 117 | 44 | 7 | By Edward Bartow. |
| 12 | ...do..... | Short Creek, west of Empire.. | 1.2 | 0 | ........ | ........ | 15 | $SO_4$ greater than 626. By Edward Bartow. |
| 13 | ...do..... | Spring River, west of Empire.. | .0 | .0 | 89 | 59 | 7 | By Edward Bartow. |
| 14 | ...do..... | Shawnee Creek, 3 miles north and 2 miles west of Empire. | .5 | .0 | 54 | 40 | 4 | Do. |
| 15 | ...do..... | Short Creek, above Galena..... | 1.0 | .0 | 50 | 246 | 9 | Do. |
| 16 | July 12 | Shoal Creek, at waterworks, Galena. | .0 | 0 | 119 | [a] Trace. | 4 | Do. |
| 17 | July 14 | Brush Creek, at ford 1 mile south and 1 mile east of Columbus. | .8 | .0 | 222 | 71 | 61 | Do. |
| 18 | July 10 | Brush Creek, 3 miles north of Baxter Springs. | .0 | .0 | 18 | 47 | 7 | Do. |
| 19 | ...do..... | Willow Creek, 1 mile north of Baxter Springs. | .0 | .0 | 49 | 60 | 4 | Do. |
| 20 | ...do..... | Spring Creek, below Baxter Springs. | 1.2 | 0 | 79 | 83 | 10 | Do. |
| 21 | ...do..... | Spring River, below dam at Baxter Springs. | Trace. | .0 | 96 | 47 | 10 | Do. |

[a] Less than 35 parts per million.

The results of water assays of Spring River and its tributaries in Kansas are recorded in Table 185. Tests of the water of Cow Creek and its tributaries (assays 1 to 7, Table 185), show waters low in bicarbonates and all, except No. 1, indicate high sulphates. The test of Little Cow Creek east of Pittsburg (assay 7, Table 185) is interesting, for it shows the water to be so highly polluted by mine drainage that it is acid. The other assays that appear in Table 185 should be studied in connection with E. H. S. Bailey's discussion of the pollution of Spring River by mine drainage, pp. 351–354.

## POLLUTION OF STREAMS BY WASTE FROM OIL REFINERIES.

In Kansas the pollution of some of the streams by the wastes from oil refineries is a serious matter. The polluting wastes are of two kinds—first, those arising from leakage of the crude oil, and, second, those caused by the discharge of chemicals used in purifying the distilled oil. The first comes from the escape of crude oil from pipe lines that carry it to the refineries, and from vats and barrels in which it is stored at the refineries. This sort of pollution is generally accidental, for crude oil is valuable and refiners and producers do not intend that much of it shall escape. Still some streams are always streaked with oil from the leakage of pipe lines which cross them. It is said that the oil entangles clay particles that are held in suspension by the waters of the streams and then sinks, making the bottoms of those streams which are much polluted by crude oil very foul. No attempt has been made to verify this statement.

Polluting wastes of the second kind are made up of the acids and alkalies that are used in treating the burning-oil distillate in the agitators. S. P. Sadtler, in his "Industrial organic chemistry," (3d ed., p. 21), divides the products from the distillation of crude oil into three parts—(*a*) benzoin distillate, (*b*) burning-oil distillate, and (*c*) residuum. No important polluting wastes from (*a*) and (*b*) result, but in the purification of (*b*) sometimes all, and always a part, of the acid and alkali wastes are discharged in the streams. The process of purification of (*b*) is described by Sadtler,[1] as follows:

The burning-oil distillate must be freed from the empyreumatic products resulting from the distillation, which give it both color and disagreeable odor. To effect this it is subjected to a treatment with sulphuric acid, washing with water and a solution of caustic soda. This operation is conducted in tall cylindrical tanks of wrought iron, lined with sheet lead, which are called "agitators." The bottom is funnel shaped, terminating in a pipe furnished with a stopcock for drawing off the refuse acid and soda washings. The distillate to be treated must be cooled to at least 60° F., and before the main body of acid is added for the treatment any water present must be carefully withdrawn. This is done by starting the agitation of the oil by the air pump and introducing a small quantity of acid. This is allowed to settle, and withdrawn. The oil is now agitated, and about one-half of the charge of acid is introduced gradually from above. The agitation is now to be continued as long as action is indicated by rise of temperature, when the dark "sludge acid" is allowed to settle, and withdrawn. The remaining portion of acid is added, and a second thorough agitation takes place. The whole charge of acid needed for an average distillate is about one and one-half to two per cent, or about six pounds of acid to the barrel of oil. The acid, as drawn off, is dark blue or reddish brown in color, and is charged with the sulphocompounds of the olefines, while free sulphur dioxide gas is present in abundance. The oil, after treatment, consists of the paraffin hydrocarbons almost freed from admixture with olefines. In color it has been changed from brownish yellow to a very light straw shade. The oil is now washed with water introduced through a perforated pipe running around the upper circumference of the tank. This water percolates through the body of the oil, removes the acid, and is allowed to escape in a constant stream from the bottom. When the wash water shows no appreciable acid taste or reaction, the washing is stopped, and about one per cent of a caustic soda solution of 12° Baumé is introduced, and the oil is again agitated. When this is drawn off the oil is ready for the settling tanks. A washing with water after the soda treatment is sometimes followed, but it is not general. A washing with dilute ammonia is also sometimes used to remove the dissolved sulphocompounds.

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[1] Op. cit., p. 24.

# PRELIMINARY REPORT ON STREAM POLLUTION BY MINE WATERS IN SOUTHEASTERN KANSAS.

By E. H. S. Bailey.

## INTRODUCTION.

The region comprising southeastern Kansas and southwestern Missouri has become of great economic importance because of its lead and zinc mines, which yielded in 1909 about 9 per cent of the total lead output and almost 50 per cent of the total zinc output of the United States. Joplin and Webb City, Mo., are its mining centers, but the mining area extends from Springfield and Aurora, Mo., to Miami, Okla., a distance of 90 miles.

Important lead and zinc deposits were discovered in this area as long ago as 1850, but they were not extensively opened until 1870. Ore was first mined in Kansas in the vicinity of Galena, and a little later a company was formed to operate mines near Baxter Springs and Lowell. In 1876 ore was found along Shoal Creek, and in 1877 at least 10,000 people poured into the camp, which formed the nucleus of the cities of Empire and Galena. Since that time the whole Joplin region has developed rapidly, and it is now one of the most important producers of lead and zinc ores in the world. In 1909 the output of the mines of the Joplin district was valued at $13,959,769.

The ores of the region here discussed (Cherokee County, Kans.) consist of lead sulphide (galena, $PbS$), zinc sulphide (blende, $ZnS$), with some zinc carbonate (smithsonite, $ZnCO_3$) and zinc silicate (calamine, $ZnSiO_4 . H_2O$). These minerals occur very intimately associated with shale, chert, and limestone.

The Kansas lead and zinc region is part of the Ozark area and lies 900 to 1,100 feet above sea level. It is drained southward into Spring River, whose waters reach the Arkansas by way of the Neosho and whose tributaries, beginning on the north, are Center, Turkey, Shawnee, Short, and Shoal creeks. Center Creek enters Spring River about 3 miles north of Galena, on the Kansas-Missouri line; Shoal Creek flows south of Galena and empties into Spring River at Lowell, about 4 miles west of Galena; Shawnee Creek enters Spring River about 3 miles northwest of Galena and drains an area in Kansas to the north and west of this point. These streams not only carry the drainage of the lead and zinc mines to the east in Missouri, but they carry also the drainage and sewage of Galena, Joplin, Carthage, Webb City, and many mining camps. The drainage from the mines in the vicinity of Baxter Springs, situated below Lowell on Spring River within a mile of the Oklahoma line, is not here considered.

With the growing industrial importance of the region the question of a satisfactory water supply for the people and the related question of the pollution of streams by mine drainage as well as by city sewage have acquired great economic interest. But little systematic study of the effect of the pollution of streams by industrial wastes has thus far been carried on in any section of the county, although it is conceded that such pollution may render the waters unfit for domestic or municipal supplies, may result in killing fish, and may lead to extensive litigation.

In the mining industry the water supply is of particular inportance, for water is required not only for milling ores but as feed for boilers, and if not found in abundance near the mines it must be brought from a distance. In many localities surface water is collected for use at the mines.

On the other hand, trouble may result from an excess of water, for in many mines water accumulates rapidly and its removal may occasion great expense. This mine water is due in part to the rainfall on the surface, but it is in part also underground water which finds its way through the lower strata from the more elevated Ozark dome to the southeast.[1] As this water is frequently used several times in the mills, every opportunity is afforded it to dissolve any sulphate of lead, zinc, and iron that may have formed in the process of oxidation of the sulphides. The particles of ore in the immense piles of gravel and tailings in the vicinity of the mines oxidize rapidly on being exposed to the weather, so that this is a source of sulphates by no means to be neglected. In the case of iron sulphide this oxidation can be represented by the equation $2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4$. An acid sulphate water is the result of the oxidation. The iron would be mostly in the ferrous state until oxidized by contact with the air for some time.

In the abandoned workings, especially those that are well ventilated, the oxidation of zinc, lead, and iron minerals takes place rapidly, so that sometimes the mine water is very strongly impregnated with mineral salts; but notwithstanding these impurities the acid mine water is often the best that can be obtained for use in the mills.

It is evident that the quality of the water finally discharged from the mine and mill is much influenced by the original character of the water used. If the original water supply runs through granite or

[1] Kansas Univ. Geol. Survey, vol. 18, p. 97.

sandstone rocks, the water will usually contain little dissolved mineral matter, but if it passes through beds of limestone or gypsum it will carry more or less of these minerals in solution and will be known as a "hard" water.

## WATERS ANALYZED.

The samples of water analyzed were obtained in the vicinity of Galena and Empire, Kans. The locality where each sample was taken is indicated on the accompanying map (fig. 1, p. 352). When the samples were collected the streams were only slightly above the ordinary stage.

Some of the waters examined came from Spring River and its tributaries, some were from the concentrated waste of the mills, and others from abandoned workings.

## WATER FROM SPRING RIVER AND ITS TRIBUTARIES.

### CHARACTER OF WATER.

The results of the analyses of samples taken from Spring River and its tributaries are shown in Table 186. Additional information in regard to the samples is given in the paragraphs following the table, which are numbered to correspond with the numbered columns.

TABLE 186.—*Analyses of water of Spring River and its tributaries.*

[Samples collected by E. H. S. Bailey; quantities in parts per million.]

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 25.4 | 39.4 | 29.3 | 621.9 | 14.0 | 23.1 | 8.1 | 8.0 | 3.2 | 6.4 | 16.0 |
| Fe | 4.6 | 4.8 | 12.5 | 62.7 | 2.5 | 12.1 | 9.8 | .5 | 3.0 | 2.0 | 2.4 |
| Al | 3.4 | 3.6 | 9.4 | 34.3 | 1.8 | 4.5 | 7.4 | | | | |
| Ca | 52.6 | 59.4 | 162.9 | 206.8 | 43.2 | 67.2 | 40.4 | 69.0 | 68.0 | 91.0 | 50.0 |
| Mg | 4.5 | 2.8 | | 21.3 | 7.3 | 2.8 | 2.7 | 5.7 | 2.1 | 14.0 | 4.2 |
| Zn | 16.2 | .3 | 47.3 | 732.0 | 3.7 | 11.0 | 10.0 | | | | |
| $SO_4$ | 70.0 | 79.3 | 307.8 | 1,624.8 | 157.2 | 15.6 | 19.0 | 80.0 | 72.0 | 77.0 | 25.0 |
| $CO_3$ | | 4.0 | 24.2 | | | | | 2.4 | | | |
| Cl | | | | 136.4 | | 49.0 | | 7.6 | 7.5 | 5.5 | 4.2 |
| Na | | | | | | | | 24.0 | 18.0 | 31.0 | |
| $NO_3$ | | | | | | | | 2.9 | 4.5 | 4.5 | 2.8 |
| $HCO_3$ | | | | | | | | 171.0 | 157.0 | 165.0 | |
| Total solids | 279.6 | 270.8 | 859.2 | 3,833.0 | 228.0 | 198.8 | 179.2 | 268.0 | 250.0 | 256.0 | 178.0 |

1. Spring River above Badger; sample taken March 31, 1905, on right bank, just above a deep ford and immediately above the intake of the pump of the near-by mills; river at about medium stage. The stream at this point is rapid. The mine water from the neighboring mines is said not to be as hard as that from some of the older mines. River water is used for the boilers and is said not to corrode them seriously. The sample represents the water as it enters Kansas, after the river has received most of the drainage of Carthage, Mo., and of many mining camps.

2. Center Creek; sample taken March 31, 1905, at a point about 200 feet below the Smithfield Ford, Mo.; current rapid and running over pebbles. At this stage the ford was passable for a buggy. Nearest mine drainage, 1½ miles above sampling point. This stream had received the drainage of Webb City and Carterville, Mo., as well as of a number of mines.

3. Turkey Creek; sample taken March 31, 1905, on the right bank, at the Niedler Ford of Spring River and Turkey Creek, about 50 feet below the Turkey Creek bridge,

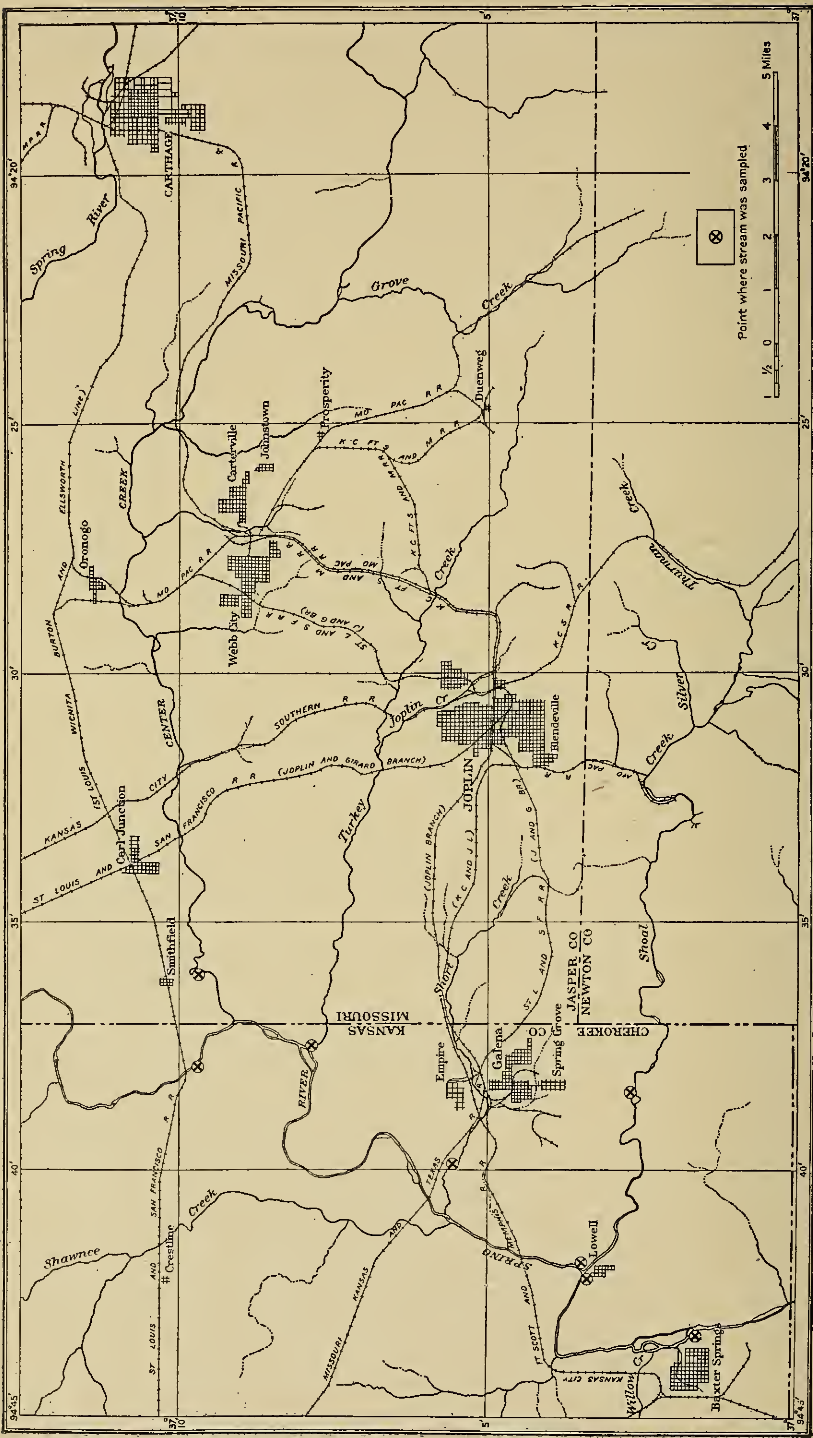


FIGURE 1.—Map illustrating stream pollution by mine drainage.

about 600 feet above the junction of the creek with Spring River, and only a few hundred feet west of the Kansas-Missouri line. Owing to back water from Spring River, the current was not rapid, but the sample was not contaminated with Spring River water. Turkey Creek carries most of the sewage of Joplin, Mo., as well as the drainage of a large number of mines and adjacent settlements.

4. Short Creek; sample taken April 1, 1905, about one-half mile above the mouth of the stream, not far from Chico Spring. Water tastes astringent. This water contains most of the drainage of Empire and Galena, Kans., and that from numerous mines and mills.

5. Spring River above the dam at Lowell; sample taken March 30, 1905, on the left bank of the stream. No opportunity for contamination from Shoal Creek. Not much mine drainage between this point and the mouth of Short Creek. Shawnee Creek, which drains an agricultural country, flows into Spring River from the west about 3 miles above this place.

6. Shoal Creek; sample taken March 30, 1905, above the bridge at the Galena waterworks, directly south of the city of Galena. The river was somewhat above the ordinary stage and the water was slightly turbid. The water is of such character and contains so much dissolved "mineral" that it produces severe griping and has a cathartic action if used by those who are not accustomed to it. This is due no doubt to the salts of zinc that are in solution. This is the only sample taken from this branch of Spring River, which flows into the main stream at Lowell.

7. Spring River below the dam; sample taken March 30, 1905, on the left bank, near the bank, and probably contains a larger proportion of Shoal Creek water than of the main stream. Much of this water had already come over the wheels of the mill.

8. Spring River at Baxter Springs; average of ten samples taken daily between December 11 and 20, 1906. These samples were collected for the purpose of making a sanitary analysis in connection with the work of the United States Geological Survey and the State Water Survey.

9. Spring River at Baxter Springs; samples collected for purpose stated in No. 8, April 5 to 15, 1907.

10. Spring River at Baxter Springs; samples collected as in Nos. 8 and 9, August 12 to 22, 1907.

11. City supply of Carthage, Mo.; this supply is from Spring River; sample taken March 7, 1904.[1]

### COMPARISON OF SULPHATES.

Comparing the amount of the sulphate shown in the different analyses of the foregoing table, it is interesting to note that Spring River at Carthage (analysis 11), the farthest point upstream at which samples were taken, contained 25 parts per million $SO_4$. Above Badger (1) where it had received the drainage of Carthage and mines in this vicinity the $SO_4$ was 70. The river water is then diluted with the waters of Center Creek (2), which drains Webb City, Carthage, Oronogo, and Carl Junction, and which carries sulphates to the amount of 79.3. This combined stream then receives the waters of Turkey Creek (3), which comes in laden with the drainage of a large part of the city of Joplin and camps in the vicinity and which carries a still larger amount of sulphates—307.8 parts. The next tributary is Short Creek (4), a small stream which carries the drainage of Empire and Galena, Kans., and of a large number of mines in the

[1] Underground water of Missouri: Bull. Missouri State Board of Health, 1904, p. 204.

vicinity. This is the most concentrated of the streams running into Spring River, and shows 1,624.8 parts per million of $SO_4$.

The next sample was taken from above the dam at Lowell (5), after Spring River had been diluted by the waters of Shawnee Creek, which flows mainly through an agricultural country in Cherokee County, Kans. This sample showed 157.2 parts of $SO_4$. The water of Shoal Creek (6), sample taken south of the city of Galena less than 5 miles above Lowell, shows the presence of 15.6 parts of $SO_4$. Sample No. 7 was taken from the river near the left bank, below the dam at Lowell, and its composition evidently represents mostly Shoal Creek water, as it contains only 19 parts of $SO_4$. At Baxter Springs, 5 miles farther down as the river runs, we find an average of 76 parts of $SO_4$. It is important to observe that these samples were taken at widely different seasons of the year, and each sample was made up of collections for 10 days, so that the figures given must closely represent the average proportion of sulphates.

The amount of sulphates present in the waters seems to be the best indication of the impurity caused by the drainage of the mines. The calcium varies within wide limits, but this may be due to the action of free sulphuric acid on limestone in the mine and in suspension in the streams. The calcium does not vary in the same proportion as the sulphates.

Since the zinc seems to diminish in quantity, the question arises whether this diminution is due merely to dilution with waters of other streams or to precipitation by calcium and magnesium carbonates in solution in the water. As there still remains in the water at Lowell more $SO_4$ than is found in the water in the upper part of the course of the stream, it would seem to indicate that much of the zinc had been precipitated, otherwise it would have increased proportionately with the sulphates.

No data are at hand to show the amount of water flowing in Spring River or the difference between high and low water. When this information is available it will be interesting to calculate the total amount of zinc that is dissolved by these waters and carried away. In the larger streams the acid has been neutralized by the carbonates of calcium and magnesium, thus: $ZnSO_4 + CaH_2(CO_3)_2$[or $MgH_2(CO_3)_2$] $= ZnCO_3 + CaSO_4 + H_2O + CO_2$. In this case the water usually gives an alkaline reaction, but this was not the case with the more concentrated samples. This acidity was especially noticeable in Short Creek (4) and in the small streams which carried the drainage of the mines and the wash water from the mills. Analyses of water of this class are given in Table 187.

## WATER FROM MINES AND CONCENTRATION MILLS.

Having considered the streams which carry away the refuse of this zinc-lead mining district, it will be of interest to go back to the source of these peculiar waters. Originally most of these waters are either ground waters—what would be called well waters in other localities—or they are surface and rain waters stored for use in the mechanical processes of preparing the ore for the smelters. They are often pumped over and over again, each time becoming more heavily loaded with mineral matter, especially the sulphates of iron and zinc.

The following table of analyses shows the quality of these waters:

TABLE 187.—*Analyses of waters from mines and from concentration mills.*

| | 10 | 11 [a] | 12 | 13 | 14 | 15 [b] | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 26.4 | 27.6 | 20.3 | 20.2 | 17.6 | 320.7 | 1,020.0 | 76.0 | 134.0 | 58.2 | 59.4 |
| Fe | 399.3 | 1.8 | 5.2 | 6.4 | 4.8 | 264.5 | 855.8 | 309.1 | 404.9 | 237.3 | 200.8 |
| Al | 302.3 | 1.4 | 15.4 | 8.6 | 16.3 | 76.0 | 288.5 | 186.8 | 149.6 | 107.7 | 140.0 |
| Ca | 291.3 | 204.3 | 497.1 | 452.0 | 148.6 | 136.1 | 237.9 | 308.0 | 259.4 | 280.6 | 293.0 |
| Mg | 19.2 | 37.0 | 24.3 | 51.9 | 22.9 | 150.5 | 223.7 | 40.5 | 42.2 | 22.4 | 22.4 |
| Zn | 1,071.3 | 1,266.0 | 1,400.2 | 1,238.2 | 1,332.2 | 787.1 | 734.1 | 1,852.9 | 1,679.5 | 857.5 | 677.9 |
| $SO_4$ | 3,459.2 | 307.8 | 2,521.1 | 2,342.8 | 2,708.8 | 3,322.8 | 5,542.8 | 3,147.0 | 4,789.9 | 3,028.2 | 2,635.8 |
| Cl | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 23.0 | 22.0 | 38.0 | 20.0 |
| Mn | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 9.8 | 4.8 | 4.7 | 311.2 |
| Pb | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 5.7 | 37.0 | ........ | ........ |
| Total solids | [illegible],664.0 | 1,884.0 | 4,853.2 | 4,437.0 | 5,144.0 | 6,323.0 | 10,169.0 | 8,871.0 | 8,576.0 | 5,058.0 | 4,355.0 |

[a] Also contains 1.9 parts of lead.

[b] Manganese, 46.6 parts.

The samples were all obtained in the vicinity of Galena and were collected March 30, 31, and April 1, 1905. The following paragraphs give additional information.

10. Alabama Coon, New York Zinc Co.; water from one of the most important pumps of the district; drainage water from 112-foot level at this time. The capacity of the pump is 500 gallons per minute. A steam vacuum pump and lift are used. This is the center of the mining district southwest of Galena. Here the workings and piles of tailings are so numerous as to leave little ground unoccupied. By the miners this water is considered bad. It corrodes iron pipes so rapidly that wood-lined pipes with brass fittings and valves have been used.

11. Water from the Murphy-Friel sludge mill. This water is allowed to settle and is siphoned off as soon as it is clear. It has been used at least seven times in various mills when drawn from the mine. Some of the material is washed six or seven times. The water contains but little iron sulphide.

12. Water from Dead Pond, 100-foot level, South Side Mining Co.

13. Sample taken from the 125-foot level, Short Creek Valley.

14. From 150-foot level, South Side Mining Co.

15. Sample of drainage from New York Zinc Co. mine near Riceville.

16. Water pumped from mine in Empire, 115-foot level.

Samples 17–20 were obtained through the kindness of H. N. Parker, of the United States Geological Survey, December 15, 1905:

17. Sample from Columbia mine.

18. From Maggie Murphy mine, one of the best-known mines of the district.

19. Water from Alabama Coon mine, same as No. 10 but collected on a different date.

20. From the Red Bird mine.

As an illustration of the hypothetical combination possible in these waters, the analysis of the Red Bird mine water (20) may be cited.

TABLE 188.—*Analysis of water from Red Bird mine.*

| | Grams per liter. |
|---|---|
| Silica ($SiO_2$) | 0.0594 |
| Calcium sulphate ($CaSO_4$) | .9954 |
| Ferrous sulphate ($FeSO_4$)[1] | .5448 |
| Aluminum sulphate ($Al_2(SO_4)_3$) | .8882 |
| Magnesium sulphate ($MgSO_4$) | .1118 |
| Zinc sulphate ($ZnSO_4$) | 1.6792 |
| Sodium chloride (NaCl) | .0330 |
| | 4.3118 |

In only a few of the samples was lead found. We should expect the lead to be precipitated in the presence of sulphate ions unless the water contained organic substances. One liter of water dissolves 0.041 gram of lead sulphate, but an acid sulphate water would probably dissolve less, because the presence of free acid diminishes the solubility of lead sulphate.

Mr. W. G. Waring, of Webb City, Mo., has kindly furnished the following list of determinations of zinc, iron, and sulphuric acid from his records:

TABLE 189.—*Analyses of mine waters.*

[From records of W. G. Waring. Quantities in grams per liter.]

| | Zinc. | Iron. | Ferrous iron. | Ferric iron. | $H_2SO_4$. | |
|---|---|---|---|---|---|---|
| | | | | | Free. | Combined. |
| Prosperity Creek | 0.003 | | | | | |
| Joplin city water | .004 | | | | | |
| Maggie Murphy | 5.500 | | | | | |
| Mine water, Tuckahoe | .414 | 0.195 | | | | |
| Walker & Co.'s mine (Joplin) | .073 | | | | | |
| C. B. Dahlgren's mine | .390 | | | | | |
| Houghland's mine | .450 | .140 | | | | |
| Bates-Cotter mine, No. 2 (Galena) | 1.310 | | | | | |
| Alix mine | .415 | .123 | | | | |
| Gate City mine | .450 | .362 | | | | |
| Maggie Murphy | 3.582 | .202 | | | | |
| Alabama Coon | .411 | .177 | | | | |
| McCann mine | .120 | .035 | | | | |
| Drilled well, Monaco mine | .125 | .015 | | | | |
| Maggie Murpby | 3.217 | .355 | | | | |
| Continental | .262 | .009 | | | | |
| Nesbitt | 3.970 | 3.160 | | | | |
| Hardy pump shaft | 2.670 | 4.087 | | | | |
| Duenweg, south end | 4.290 | 3.295 | | | | |
| Same, precipitated with $H_2S$ | 4.337 | | | | | |
| Duenweg, west end | .172 | .170 | | | | |
| Blue Goose | .172 | .170 | | | | |
| Blue Goose, No. 1 | .135 | .115 | | | | |
| Clover Dale, Midway | .047 | .000 | | | | |
| Prairie Bell | .260 | .009 | | | | |
| Victor | .361 | | | | | |
| Victor, second sample | .897 | | | | | |
| Jeff, No. 1 | 3.000 | .050 | | | | |
| Modoc mine | .153 | None. | | | | |
| Gum Spring | .012 | | | | | |
| Maggie Murphy | 2.690 | | .402 | | .167 | |
| Alabama Coon | 2.807 | | .322 | | .186 | |
| Columbia, New York Co | 1.548 | | .464 | | .157 | |
| Monte Cristo, New York Co | 1.905 | | .210 | | .127 | |
| Dwight, New York Co | .935 | | .291 | | .137 | |
| Maggie Murphy | 5.516 | | .274 | .027 | 1.550 | 10.147 |
| Coppinger & Fiske mine, Carterville | .209 | | .027 | | | 1.873 |
| Alix mine | .465 | | .163 | | | 1.645 |
| Stevens mine, Joplin | .075 | | .060 | | | 1.680 |
| S. T. Nesbitt, Tuckahoe | .420 | | .482 | | | 3.240 |
| T. P. Steers | 1.055 | | .510 | | .668 | |
| St. Anthony, Carterville | 4.867 | | 4.150 | 2.300 | 2.273 | |

[1] Partly oxidized.

In the discussion of these waters Mr. Waring says that the waters in ore-bearing rocks are usually devoid of zinc, iron, and calcium sulphate, and are devoid of free sulphuric acid when the ore deposits are first opened. After the metallic sulphides, especially $FeS_2$, have been exposed to the free air by pumping the water away from them and after they are again leached the waters become highly charged with these metallic sulphates. The best condition for solution seems to be, then, alternate drying and contact with water. In some places where extensive pyrite beds lie above the zinc ore, as in the Galena mines, it is a well-known fact that the water will be fairly free from mineral matter after having been pumped down, if it is kept down; but when the water rises again in a mine, on account of stoppage of pumping, so that the water gets into the timbers, the water becomes excessively acid. These conditions are recognized by mine foremen as those which will present the best opportunity for the oxidation of the sulphides. At the Victor mine, contrary to the usual conditions, the water became low in iron and zinc after the pumps were stopped for some time, and the percentage increased again shortly after starting up.

It is interesting, also, to note that when deep wells—those from 900 to 1,000 feet deep—are properly cased the water shows no trace of sulphates, but it shows about 2 milligrams of nitrogen as nitrates per liter.

Some of the waters mentioned in Mr. Waring's report are from mines in the vicinity of Galena and others in the vicinity of Joplin, Mo. Occasionally waters are found, as, for instance, the last in the list, which contain quite large quantities of cadmium.

## COAL-MINE WATERS.

It seems to be fairly well established that the Kansas "Coal Measures" rest on the "Subcarboniferous" limestone. The Mississippian or "Subcarboniferous" rocks, which underlie the coal measures, are found only in the southeastern corner of the State. The coal measures proper are nearly 3,000 feet thick and are composed of alternating beds of limestone, sandstones, and shales. The Cherokee shale is at the base of the coal measures and carries the largest bed of coal known in Kansas—the Weir-Pittsburg coal. This bed averages about 40 inches in thickness and is from 60 to 100 feet below the surface. The mine waters examined came from this region. The coal-mining industry is of great importance in the State. Coal is mined especially in Cherokee, Crawford, Franklin, Leavenworth, Linn, and Osage counties. Over 7,000,000 tons were mined in the State in 1907.

Analyses 21 to 25, Table 190, represent the composition of the coal-mine waters.

TABLE 190.—*Composition of coal-mine waters.*

[Parts per million.]

| | 21 [a] | 22 | 23 | 24 | 25 [b] |
|---|---|---|---|---|---|
| $SiO_2$ | 56.1 | 195.7 | 51.4 | 25.0 | 176.2 |
| Fe | 305.6 | 1,559.0 | 127.0 | 51.3 | 2,736.0 |
| Al | 385.8 | 542.0 | 11.3 | 10.3 | 114.8 |
| Ca | 489.9 | 667.3 | 279.8 | 246.3 | 458.1 |
| Mg | 492.4 | 723.3 | 137.1 | 78.3 | 509.4 |
| $SO_4$ | 6,137.9 | 11,873.9 | 2,618.3 | 2,121.6 | 12,124.0 |
| Cl | 74.8 | | | | 36.0 |
| Total solids | 11,985 | 18,080 | 4,561 | 3,740 | 19,729 |

[a] Samples taken April 4, 1905.
[b] Sample taken December 13, 1906, by H. N. Parker, U. S. Geol. Survey. Contained considerable manganese.

21. From Clemens-Schlanger Coal Co. mine No. 1, 1 mile north of Pittsburg; by Mr. Jones. Water is handled by a steam pump with 2-inch suction and 1½-inch discharge, which runs 8 hours out of 24.

22. From mine 3½ miles northeast of Pittsburg; by Mr. Fitzpatrick.

23. Water from Pittsburg No. 8 shaft, Mount Carmel Coal Co.; by Mr. Osborn.

24. Sample from Pittsburg No. 5 shaft, Mount Carmel Coal Co., near Chicopee; by Mr. Osborn.

25. Sample from No. 8 shaft, Mount Carmel Coal Co.; sump had been pumped out once during morning.

The analyses show these waters to have the usual composition of coal-mine waters. They contain large quantities of iron sulphate and sulphuric acid, produced by the oxidation of the pyrite which is mixed with the coal. The equation showing their action would be $2FeS_2+7O_2+2H_2SO_4=2FeSO_4+2H_2SO_4$. The iron, which is at first in a ferrous state, is oxidized on standing in accordance with the reaction $4FeSO_4+O_2+2H_2SO_4=2Fe_2(SO_4)_3+2H_2O$; hydrolysis takes place, and the ferric hydrate is precipitated as a reddish-brown deposit. This latter change may be illustrated by the equation $Fe_2(SO_4)+6H_2O=2Fe(OH)_3+3H_2SO_4$.

This occurs to some extent in the mines, but especially in the streams that carry away the mine drainage. Often the iron is no more abundant than in the zinc mine waters, but the sulphates in these samples averaged higher than in the zinc waters. In one sample (No. 25) the solids amounted to as much as 1,152 grains per gallon. Water of this character, when it finds its way into neighboring streams, is largely diluted, its iron is precipitated, its free acid is neutralized by contact with the lime contained in the water, and although calcium sulphate is thus formed, the quality of the product is much improved so that it may be used for some domestic purposes. The latter reaction would be expressed by the equation $H_2SO_4+CaCO_3=CaSO_4+H_2O+CO_2$.

## EFFECT OF MINE WATERS ON FISH.

In regard to the action of these waters on the animal life of the streams, M. C. Marsh [1] says: "The reaction of water which will sup-

[1] Water-Supply Paper U. S. Geol. Survey No. 192, 1907, p. 337.

port fish life must be slightly alkaline. When the water becomes even slightly acid, fish can not live in it, and in the experimenting with acid pollutions the alkalinity of the water used as a diluent of course affects the results."

In this special case whenever the point of acidity has been reached there is no doubt that the water is poisonous, and probably a slightly acid water would produce fatal results after a longer time. As noticed above, there was in most cases enough calcium carbonate and alkali in the larger streams to maintain the alkalinity.

## EFFECT OF MINE WATERS ON METALS.

J. W. Jones,[1] in discussing the action of mine waters on metals, calls attention to the examination made of the water from the Stanley mine, Idaho Springs. This was pumped by steam, allowing the exhaust to pass into the water of the sump. Under these conditions the wrought iron pipe lasted only about a week. By substituting air for steam the life of the pipe was somewhat lengthened. After making experiments to show the action of acids upon metals, an analysis was made of the dried precipitate deposited in the water on standing. This was found to be of the following composition:

*Composition of dried precipitate in water from Stanley mine.*

| | |
|---|---|
| Ferric oxide | 53.57 |
| Aluminic oxide | 2.87 |
| Silica | 10.85 |
| Sulphurous anhydride | 11.46 |
| Water | 21.14 |
| | 99.89 |

This is evidently a hydrated basic sulphate of iron. The water filtered from the precipitate had the following composition:

*Composition of water filtered from precipitate in water from Stanley mine.*

| | Parts per thousand. |
|---|---|
| Silica | 0.0438 |
| Sodium chloride | .1340 |
| Sodium sulphate | .3117 |
| Potassium sulphate | .1555 |
| Aluminum | .0198 |
| Zinc sulphate | .1224 |
| Manganous sulphate | .4271 |
| Magnesium sulphate | .4675 |
| Calcium sulphate | .6363 |
| Ferric sulphate | .6064 |
| Ferrous sulphate | .0094 |
| Copper sulphate | .1947 |

[1] Ferric sulphate in mining waters and its action on metals: Proc. Colorado Sci. Soc., vol. 6, 1897–1900, pp. 46–55.

The corrosive action of the water is ascribed to the presence of copper sulphate, and its solvent power for copper to the ferric sulphate that is present. Free sulphuric acid was not found, although the water was distinctly acid. Experiments were tried on finely divided metals with a solution of ferric sulphate and it was found that copper, silver, antimony, and bismuth readily dissolved, while lead and gold were not acted upon. In some experiments with ferric chloride solution on the metals, it was found that lead, copper, bismuth, antimony, and to some extent silver, were dissolved. The reactions involved are represented by the following equations:

$$Cu + Fe_2(SO_4)_3 = CuSO_4 + 2FeSO_4$$
$$Ag_2 + Fe(SO_4)_3 = Ag_2SO_4 + 2FeSO_4$$
$$Pb + Fe_2Cl_6 = PbCl_2 + 2FeCl_2$$
$$2Bi + 3Fe_2Cl_6 = 2BiCl_3 + 6FeCl_2$$

The results of practical experiments on a large scale with iron pipe and lead-lined pipe showed these to be worthless. Wooden pipe lasted over a year. Copper pipe, containing a very small amount of zinc, in a short time gave way at the joints. Gutta-percha pipe was found to be too soft. Bronze had been in place for two years with good results, and it was predicted that aluminum bronze would last still better. In a discussion of this paper E. R. Kirby stated that wrought-iron pipe with wooden lining had been successfully used at Buel mine at Central City.

Philip Argall quoted the analysis of water from Ballygahan mine, Wicklow, by G. A. Kinahan, as follows:

*Analysis of water from Ballygahan mine.*

| | Parts per thousand. |
|---|---|
| Ferrous oxide | 0. 8181 |
| Ferric oxide | . 0430 |
| Copper oxide | . 0932 |
| Manganous oxide | . 0230 |
| Zinc oxide | . 0130 |
| Sulphuric acid | 6. 3426 |
| | 7. 3319 |

Mr. Argall states the standard practice in the Wicklow mines is to line cast-iron pipes with one-half inch soft pine strips. The suction pipes are of hard wood and the plungers and valves of bronze.

Ernest Le Neve Foster stated that in the Saratoga mine, Russell Gulch, the best results had been obtained by the use of a Cornish pump with clack seats and clacks made of bronze, and all other parts, including the standpipe, made of cast iron. This installation, after 20 months, showed little corrosive action of the water. The most complete analysis of the water from this mine at hand showed the following composition:

*Analysis of water from Saratoga mine.*

| | Grains per U. S. gallon. |
|---|---|
| Calcium sulphate | 1,763 |
| Magnesium sulphate | 353 |
| Sodium chloride | .59 |
| Iron sulphate | 1,379 |
| Free sulphuric acid | 3.20 |
| Sand | 696 |
| Volatile organic matter | 5.49 |

An interesting point in this connection is that the action of mine water dripping on iron is much more severe than when the iron is immersed in it, so that a series of drops of water falling on a 12-pound T-rail will cut it in two in the course of three weeks. Cast iron seems to withstand corrosive action very much better than wrought iron. A low temperature of the mine water, and the use of compressed air rather than steam for power, tend to prevent the action of the corrosive mine water on the metallic parts.

## ACKNOWLEDGMENTS.

This contribution to our knowledge of mine waters is made with the hope that it may lead to further investigation in these lines. Some of the problems that need solution have been suggested. What is the best material for pipes and pumps? What is the effect upon the quality of water of mixing ordinary waters with polluted mine waters? If such metals as lead and zinc are precipitated, in what stage of the flow of the water does this take place, and what class of waters do this most completely? Other questions that need investigation are: How can mine waters be utilized? Is it possible to recover zinc or any valuable metals from these waters? What is the effect of mine waters, as far as purification is concerned, on the sewage of cities? Can a water be made fit for city supply after being once polluted with the mine drainage? Is the use of water containing a small quantity of zinc sulphate detrimental to health, and if so, is there a practical method by which it may be removed? Some of these topics have already been taken up as part of the work of the United States Geological Survey in other portions of the country, but much remains to be done.

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